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QUANTITATIVE RISK ASSESSMENT FOR THE PROPOSED D3 ENERGY PRODUCTION RIGHT ACTIVITIES ON VARIOUS FARMS NEAR VIRGINIA IN WELKOM, FREE STATE PROVINCE

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Date of Issue: 16th of September 2026
Report No.: 26EIMS-01 Rev 2



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DOCUMENT CHANGE HISTORY			
PAGE/LINE	CHANGE	DATE	REV
Document	Initial release	7 th of July 2026	0
Document	Updated report as per clients' comments	8 th of September 2026	1
Document	Updated report as per clients' comments	16 th of September 2026	2

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Mike Oberholzer is a professional engineer, holds a Bachelor of Science in Chemical Engineering and is an approved signatory for MHI risk assessments, thereby meeting the competency requirements of SANAS for assessment of the risks of hazardous components, including fires, explosions and toxic releases.

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EXECUTIVE SUMMARY

1 INTRODUCTION

D3 Energy South Africa (Pty) Ltd (hereinafter referred to as D3 Energy) proposes to develop a gas-to-power project, including various power plants and associated infrastructure, on various farms near the City of Welkom, in the Free State Province, South Africa.

The overall project would broadly involve the following components:

- A Liquefied Natural Gas (LNG) or a Compressed Natural Gas (CNG) terminal, consisting of a berth with off-loading arms, cryogenic pipelines, storage and handling facilities and re-gasification modules;
- Gas-to-Power plant, with a 3 000 MW generation capacity;
- Gas pipelines for the transmission, distribution and reticulation of natural gas; and,
- Electricity transmission lines to evacuate electricity to the previously approved lines.

Other project related activities under the same application include the undertaking of seismic surveys and exploration drilling. The ultimate / overall proposed project will comprise of a power plant with a power generation capacity of 3 000 MW.

An EIA application has been lodged for the project.

As developers and their chosen technologies have not yet been identified, various technologically feasible and gas plant options are applied for in the EIA. The assessment presented is based on the worst-case option for each impact. The aim of this approach is to identify the envelope limits within which the project impacts will fall, and which will be acceptable to the receiving environment with implementation of mitigation measures, where relevant.

Since off-site incidents may result due to the hazards of some of the chemical components to be stored on or delivered to site, RISCUM (PTY) LTD was commissioned to conduct a quantitative risk assessment (QRA) to determine the impacts onto surrounding properties and communities as part of an environmental impact assessment (EIA).

The purpose of this report is to convey the essential details, which include a short description of the hazards, the receiving environment and the current relevant designs, as well as risks and consequences of a major incident.

1.1 Terms of Reference

The main aim of the investigation was to quantify the risks to employees, neighbours and the public with regard to the proposed D3 Energy facilities at various farms near Virginia in Welkom.

The scope of the risk assessment included:

1. Develop accidental spill and fire scenarios for the facility;
2. Using generic failure rates, determine the probability of each scenario identified, as well as potential consequences;
3. Where the consequence / risk will extend beyond the site boundary, calculate the maximum individual risk, taking into account generic failure rates, initiating events, meteorological conditions and lethality;
4. Determine and comment on the societal risk posed by the facility;
5. Recommend mitigation measures to minimise risk where required; and,
6. Identify and assess impacts, including cumulative impacts of the project.

This risk assessment is not intended to replace an MHI risk assessment nor any other legal requirement.

1.2 Purpose and Main Activities

The principal activity of the proposed D3 Energy facilities on various farms near Virginia and Welkom would be the extraction, gathering, processing and dispatch of natural gas. Gas produced from the wells would be conveyed through the underground gathering system to the central processing plant for compression or liquefaction as CNG and / or LNG.

1.3 Main Hazards Due to Substance and Process

The main hazards that would occur with a loss of containment of hazardous components at the proposed D3 Energy facilities at various farms near Virginia in Welkom include exposure to:

- Toxic vapours;
- Asphyxiant vapours;
- Thermal radiation from fires; and,
- Overpressure from explosions.

2 ENVIRONMENT

The proposed D3 Energy project, as shown in Figure 2-1, comprises the production wells, gas gathering pipelines, and the central gas processing plant for CNG and / or LNG production.

The originally approved exploration area is located over an area of approximately 149 377 hectares (ha), covering various farms near the City of Welkom, within the Free State Province, extending north from Theunissen, northeast towards Kroonstad, and east of Virginia and Hennenman.

D3 Energy were subsequently required to relinquish part of their ER land position during their second renewal which reduced the ER footprint to approximately 95 483 ha, a decrease of over 50 000 ha less than the originally approved area. The applicant wishes to convert a portion of their existing Exploration Right area (ER315) into a Production Right (PR). The proposed extraction and production will target helium and methane gas, and will consist of up to 43 production wells, gas gathering pipelines, a helium recovery and gas processing plant (CNG and / or LNG) and associated infrastructure. In addition, ongoing exploration activities will include drilling of up to 48 exploration wells, and 8 seismic transects with a combined length of ~62.5 km of seismic and / or audio magnetotelluric surveys. The proposed production right application area covers a total of ~14 440 hectares.

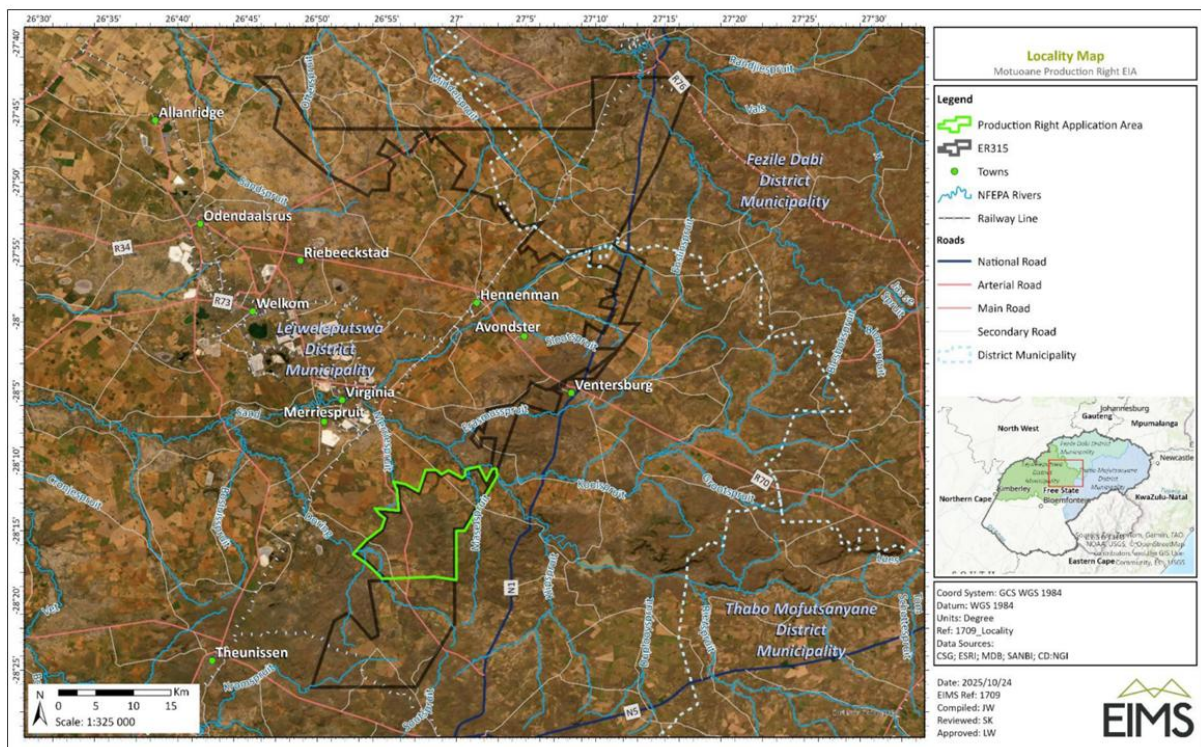


Figure 2-1: Site locality map for the gas infrastructure, with the power plant footprints

3 PROJECT DESCRIPTION

3.1 Site

The layout of the power station has not been developed. However, a typical layout of the proposed power plant facility, is shown in Figure 3-1. Each module will have a natural gas supply line, gas turbines, steam turbines, transformers, a substation, switch yard, water treatment area and a back-up fuel (LO) area. The administration building will be common for the two modules.

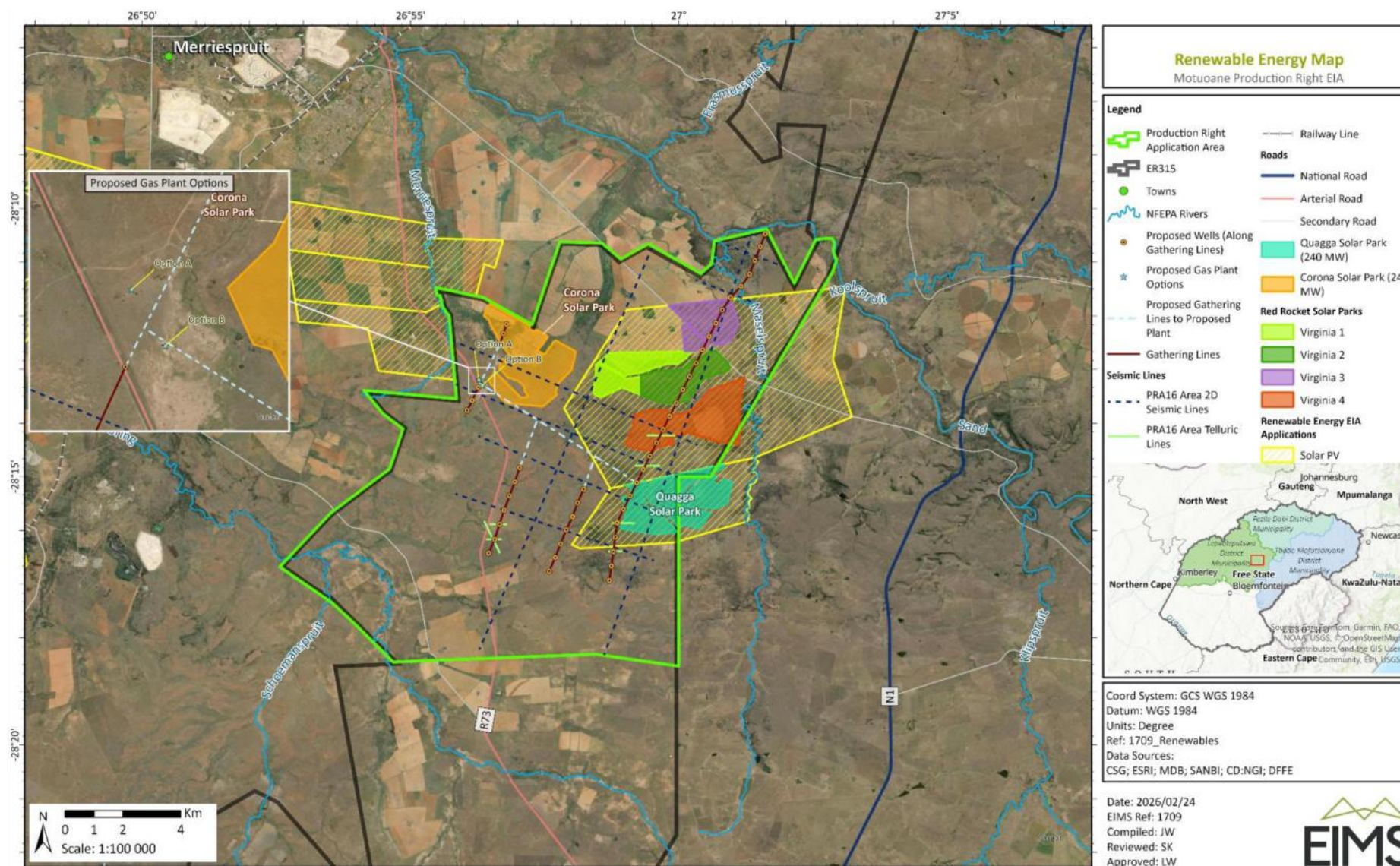


Figure 3-1: Site layout

3.2 Process Description

The proposed development of the Gas Project area will involve the following activities:

- Pre-drilling seismic and / or audio magnetotelluric surveys to optimize well locations for maximum deliverability;
- Drilling and completion of wells;
- Maintenance workovers of wells;
- Construction of gas flowline gathering systems;
- Installation of gas compression and processing facilities;
- Construction of a helium recovery facility and gas (methane) processing plant (CNG or LNG); and the,
- Construction of associated infrastructure including roads, borrow pits, communications facilities and temporary accommodation facilities, if necessary.

3.2.1 Gas Composition

The gas composition used for the Gas Project design work is shown below in Table 3-1. This is based on sample analysis taken from wells within the proposed development area.

Table 3-1: Gas Composition

Helium (%)	Methane (%)	Ethane (ppm)	Propane (ppm)	Nitrogen (%)	Carbon Dioxide (ppm)
5.6	86.5	554	>50	7.8	60

3.2.2 Well Locations

The locations of all wells and infrastructure have been chosen by using desktop studies and available information from publicly available mapping services.

All well locations, flowline gathering lines and processing plant infrastructure will be located in consultation with the landowner and will be located to minimize damage to improvements, vegetation and land. Facilities and wells will be located close to existing fence lines and tracks where practical and will not be located within close proximity to housing and major structures.

Figure 3-2 shows the proposed development locations for wells, pipelines and infrastructure. In total there are 43 well development locations that are located along known faults and close to either existing blowers or exploration wells drilled by the company. The initial development will focus on the wells located on the Virginia fault where there are 13 new well locations and 3 existing wells that will be utilised in the development.

Structure mapping has been used to position wells above the predicted gas water contact depth. This gas water contact depth assumption may change as more drilling and other geological data is gathered and may increase the number of wells in the development.

Seismic and audio magnetotelluric surveys may locate additional faults within the Gas Project and will also increase the development well numbers.

There is one central gas and helium processing plant that is connected to the production wells by gathering pipelines.

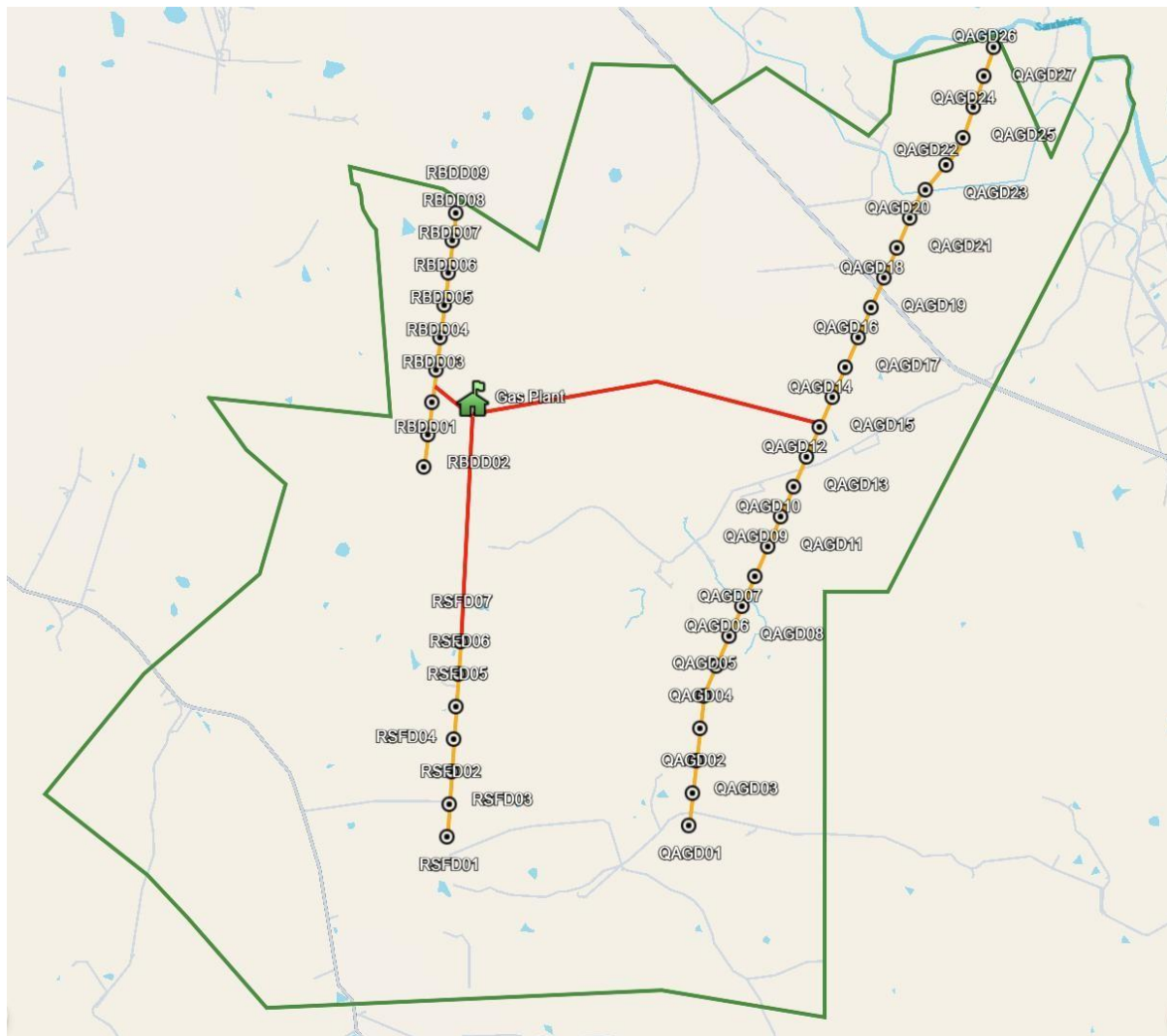


Figure 3-2: Area Wells and Facilities

Figure 3-3 shows the alternative well locations, pipeline routing and gas-processing plant locations considered for the proposed development.

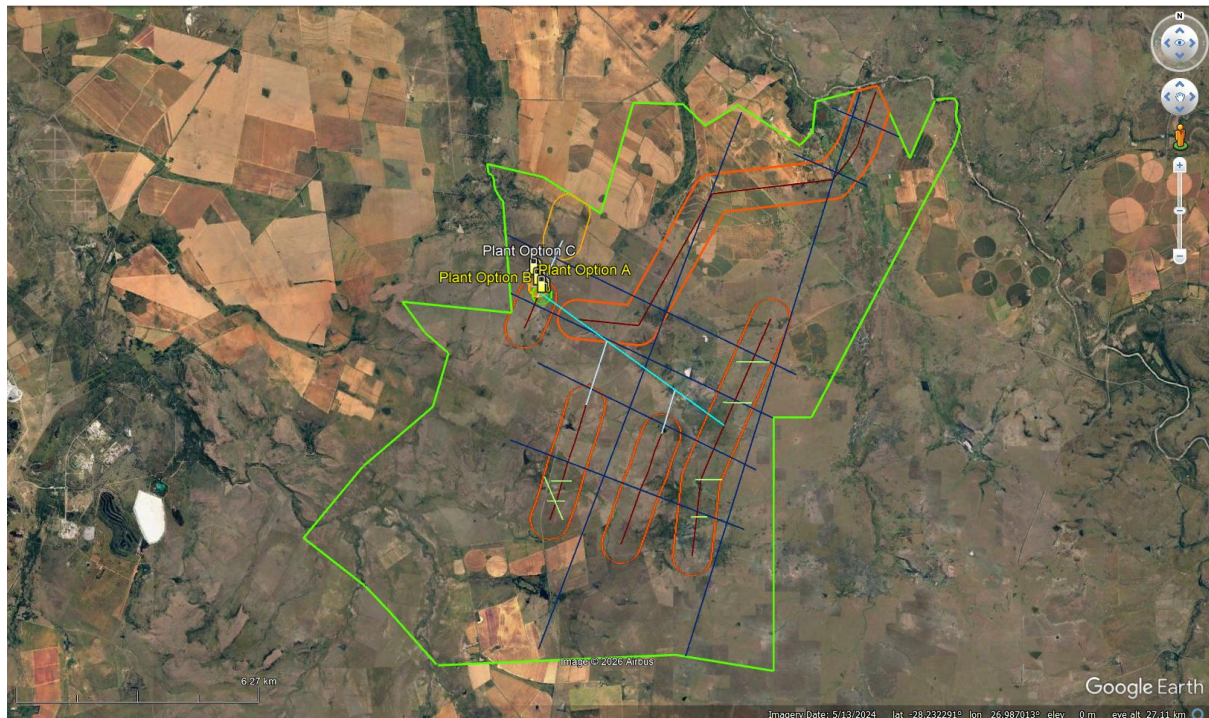


Figure 3-3: Alternative well locations, pipeline routing and gas-processing plant locations

3.2.3 Well Drilling

A development spacing of 500 m has been chosen for the wells to be drilled. This spacing has been chosen following a review of geological and reservoir properties, including well interference testing. The wells will be drilled to a total depth of approximately 500 m and will be completed open-hole in the reservoir zone. The hole diameter will mostly be 5" NB, for the hole depth.

Production casing from the surface to the base of the Karoo will be cemented to the surface to ensure wellbore integrity. Then, the well will be drilled into the Witwatersrand formation in order to encounter gas-producing fractures.

Initially, D3 Energy will log the open hole Karoo, run and set casing, then run a Casing Bond Log (CBL). Upon reaching the Total Depth (TD), D3 Energy will log the open hole beneath the casing. This logging program may evolve as drilling continues.

To the extent possible, lease construction will take place during the gathering system construction to optimize the use of earthmoving equipment and minimize impacts.

The wells will be completed as simple open hole completions, with no tubing or pumping equipment necessary.

3.2.3.1 Well Surface Facilities

The wellhead surface facilities will be simplistic in design to have a minimum footprint on the environment. As it is anticipated that there will be no liquids produced from the wells

contemplated herein, there will be no need for surface equipment such as water storage and holding tanks to be located at the wellheads. The fencing surrounding the well site will be able to be modified easily to maximise the land use available for the landowner. Consideration will also be given to having the wellsite facilities located below ground level in closed chambers to further reduce the visual and environmental impacts in some areas. Water will nevertheless be required for cementing, and a drill sump will be provided within the drill pad to contain water used during drilling activities.

Instrumentation at each well location will consist of gas meters and pressure monitoring only. These instruments will be powered by replaceable lithium batteries, so eliminating the need for any instrumentation that requires gas to be emitted and therefore reducing fugitive emissions. There will also not be a requirement to have any solar panels or battery boxes on the location, thereby reducing the chance of theft or vandalism.

3.2.3.2 Gas Gathering System

The gas gathering network covers all low-pressure underground pipework from the wellhead to the compressor station or gas processing plant. It is critical in this development to keep wellhead pressures low, as this maximizes gas and helium recovery from the field. The network pipelines have been designed to have only one gas and helium processing plant within the development area to reduce the requirement for nodal compression. This will reduce the environmental footprint and keep noise emitting equipment to fewer locations. There will be provision to have field nodal compression should the actual flow rates and pressures differ from the modelling.

The preliminary conceptual gas gathering system has been designed to minimize flowline pipe lengths and pressure loss, while maintaining the required distances from landowner and environmental constraints. As discussed previously, all locations will be subjected to review once stakeholder and landowner discussions commence.

Flow modelling has been conducted to ensure that the wellhead pressures at the wells are kept to a minimum. For an assumed plant suction pressure of 25 kPa(g) (3.5 psig), the highest pressure seen at a wellhead in the network is just over 70 kPa(g) (10.0 psig).

The sizing of the high-density polyethylene pipe (HDPE) pipelines will range from 110 mm in diameter for up to 315 mm for gas spine pipelines. The pipelines will be constructed from HDPE pipe and will be designed to use the natural flow of the land contouring to reduce the need for low point drains. Where drains are required, consideration will be given to install them in underground pits to reduce visual, environmental and landowner impacts.

3.2.4 Helium Recovery Facility and Gas Processing Plant

The helium recovery and gas processing facilities will have the optionality of producing either gaseous or liquified helium and methane, as shown in Figure 3-4, with the layout shown in Figure 3-5.

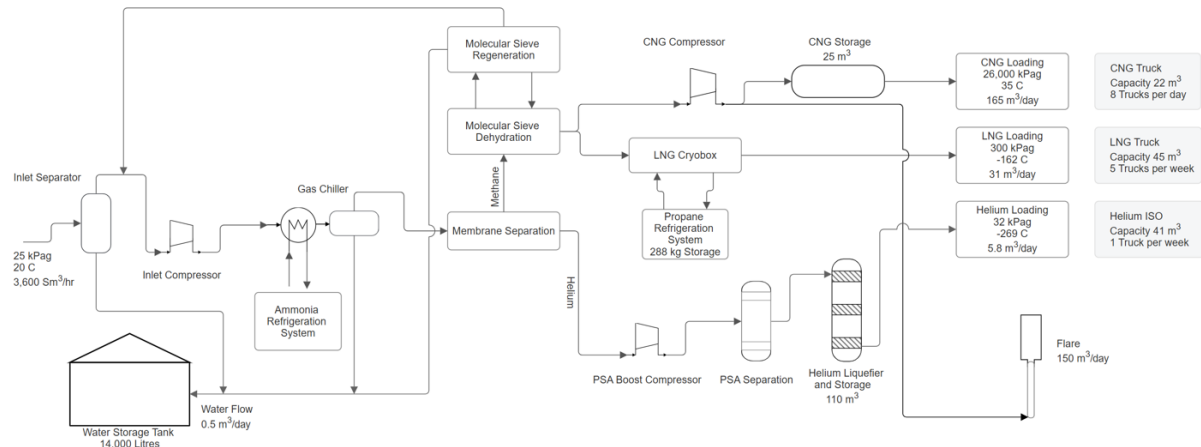


Figure 3-4: Process flow diagram for the helium and natural gas purification

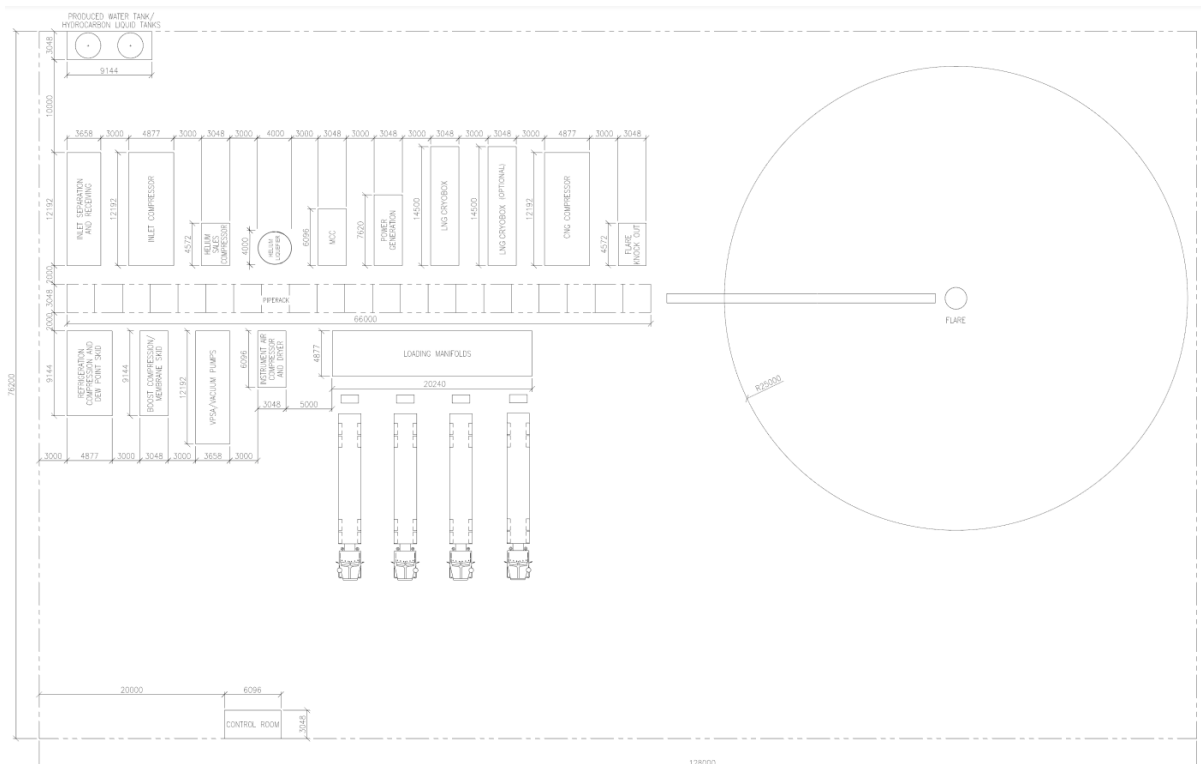


Figure 3-5: Layout of the helium and natural gas purification

A description of the helium and methane streams for gas and liquefaction processes, is given below.

The process facility will contain the components listed in Table 3-2.

Table 3-2: Components at the Gas Processing Facility

Product	Quantity	Comment
LNG	45 m ³	• Road tanker: 5 Road tankers per week • Pressure: 300 kpa(g) • Temperature: -162°C
CNG	25 m ³	• Pressure: 260 bar(g) • Temperature: -35°C
	22 m ³	• Road tankers: 8 Road tankers per day • Pressure: 260 bar(g) • Temperature: -35°C
Helium	110 m ³	• Pressure: 32 kpa(g) • Temperature: -269°C
Ammonia	Not provided - Assume 4 tonnes in total	• Refrigerant
Propane	288 kg	• Refrigerant • Pressure: Not provided - Assume ambient • Temperature: Not provided - Assume ambient

3.2.4.1 Helium Recovery

The 3.0 MMSCFD capacity helium recovery facility design features include a modular-based facility that is easily moved between sites or have additional modules added, if required. The process modules include inlet compression, pre-treatment, single stage membrane separation, pressure swing absorption (PSA) boost compression, vacuum PSA purification, helium sales compression and / or liquefaction.

The process starts with the inlet reception equipment to manage the incoming process stream to the facility. After regulating the pressure to approximately 25 kPa(g), the inlet gas is compressed to achieve the necessary pressure required to operate the membrane system. The pre-treatment module provides dew point control and removal of water that would otherwise condense in the membrane systems. The treated gas then flows to the inlet of the membrane separation system.

The membrane separation system has been designed for single stage separation. The first stage separates the bulk contaminants from the crude helium permeate stream, which flows to the PSA purification unit. The retentate stream (methane) is back-pressure controlled flowing to the package limits where it will flow into the inlet of the gas CNG or LNG facility. The crude helium from the first stage permeate is compressed on route to the PSA purification package. Within the vacuum PSA module, the crude helium stream is purified to >98% within the PSA vessels before flowing to the helium sales compressor or liquefaction unit.

For gaseous helium sales, the gas compressor is designed to deliver pressure up to 200 kPa(g) to the 3-truck loading system. The manual loading system is located at the end of the helium sales gas compressor package.

If D3 Energy decides to liquify the helium gas on the project site, the helium liquefaction unit will receive purified helium from the PSA module and will deliver grade 5 helium to the liquid helium dewar at the outlet. From the liquid helium dewar, the liquid helium can be loaded into helium ISO Tank containers for shipment.

3.2.4.2 Methane Gas Recovery

The retentate stream (methane) from the helium recovery facility will flow into the inlet of either the CNG or LNG process modules.

The CNG module will compress the gas from the inlet pressure of 2 500 kPa(g) up to the 25 000 kPa(g) required pressure for NOVO tube trailers. As with the helium system, the compressed methane will flow from the module exit to the truck loading system. The manual loading system is located at the end of the helium sales gas compressor package.

The LNG module, if installed, will take the feed gas and compress it up to the pressure required by the plant. Before liquefaction, the carbon dioxide contained in the raw natural gas may need to be removed (pending design calculations), as it will freeze under the low temperature state used in the liquefaction process and block the equipment or reduce the performance of the heat exchanger. Should the carbon dioxide removal system be required, it uses an amine liquid to reduce the carbon dioxide concentration in the raw gas to an acceptable level.

The liquefaction element adopts a propane pre-cooling mixed refrigerant refrigeration process. The pre-coolant is propane, and the mixed refrigerant is nitrogen, methane, ethylene and propane components.

The purified, predominately methane gas, will be pre-cooled by a pre-coolant before entering the cold box. Any heavy hydrocarbons in the gas stream will also freeze at low temperatures, so a heavy hydrocarbon separator is set up in the cold box to separate any condensed heavy hydrocarbons. The gas entering the cold box uses the large amount of cold released by the mixed refrigerant in the cold box to liquefy the natural gas, and the liquefied LNG is sent to the manual loading system used to fill the LNG trucks.

3.2.5 Power Generation and Network

The power supply requirements for the development will consist of:

- Auxiliary power at processing plants; and,
- Electrical-driven compressors and pumps used in the helium and methane plants.

It is planned that the power will be supplied by gas powered generators that utilise the produced gas from the plant inlet following filtration and dehydration. The system will be set up with a redundant generator with an auto changeover backup system, should a unit shutdown unexpectedly or during servicing and maintenance events. There will also be a diesel generator available for black starts when no gas supply is available.

3.2.6 Exportation Gas Pipeline

There are no transmission pipelines in the vicinity of the Gas Project area, and no pipelines are planned for this stage of the development.

3.2.6.1 Nitrogen Installation

Nitrogen is an inert gas and would be used to purge lines and equipment prior to maintenance. It is expected that nitrogen would be stored in gas cylinders or a cryogenic storage vessel or would be produced on site by removing the nitrogen from the air. This study assumes that nitrogen will be brought to site as part of maintenance, with no permanent storage.

3.2.6.2 Flare

A flare is shown in the process flow diagram and facility layout provided for this assessment (See Figure 3-4 and Figure 3-5). On that basis, a flare was included for controlled disposal of off-specification gas. The flowrate was provided as 150 m³ per day. As the flare height and pilot-fuel details were not provided, the assessment assumed a release height of 10 m above grade and no pilot-fuel requirement. These assumptions must be confirmed against the final design.

4 METHODOLOGY

The first step in any risk assessment is to identify all hazards. The merit of including a hazard for further investigation is then determined by how significant it is, normally by using a cut-off or threshold value.

Once a hazard has been identified, it is necessary to assess it in terms of the risk it presents to the employees and the neighbouring community. In principle, both the probability and the consequence should be considered, but there are occasions where, if either the probability or the consequence can be shown to be sufficiently low or sufficiently high, decisions can be made based on just one factor.

During the hazard identification component of the report, the following considerations are taken into account:

- Chemical identities;
- Location of on-site installations that use, produce, process, transport or store hazardous components;
- Type and design of containers, vessels or pipelines;
- Quantity of material that could be involved in an airborne release; and the,
- Nature of the hazard most likely to accompany hazardous materials spills or releases, e.g. airborne toxic vapours or mists, fires or explosions, large quantities to be stored and certain handling conditions of processed components.

The evaluation methodology assumes that the facility will perform as designed in the absence of unintended events such as component and material failures of equipment, human errors, external events and process unknowns.

Risk assessments done in accordance with the MHI regulations are required to be conducted according to SANS 1461 (2018). This standard is specific to the MHI risk assessment that is required to be done prior to construction and includes elements that is not usually available at the preparation, such as emergency plans and mitigation suggested during the EIA process.

SANS 1461 (2018) is based on RIVM (2009) for process plants. The latter standards describe the minimum scenarios to be included in the assessment, as well as the assumptions to be used. As full compliance of SANS 1461 (2018) cannot be achieved within the NEMA legislative framework, general compliance of the aforementioned standards would be applicable and briefly described in the sections below.

The QRA process is summarised with the following steps:

1. Identification of components that are flammable, toxic, reactive or corrosive and that have the potential to result in a major incident from fires, explosions or toxic releases;
2. Development of accidental loss of containment (LOC) scenarios for equipment containing hazardous components (including release rate, the location and orientation of the release);
3. For each incident developed in Step 2, determination of consequences (such as thermal radiation, domino effects, toxic-cloud formation and so forth); and,
4. For scenarios with off-site consequences (greater than 1% fatality off-site), calculation of maximum individual risk (MIR), taking into account all generic failure rates, initiating events (such as ignition), meteorological conditions and lethality.

Scenarios included in this QRA have impacts externally to the establishment. The 1% fatality from acute effects (thermal radiation, blast overpressure and toxic exposure) is determined as the endpoint (RIVM 2009). Thus, a scenario producing a fatality of less than 1% at the establishment boundary under worst-case meteorological conditions, would be excluded from the QRA.

5 CONCLUSIONS

Risk calculations are not precise. Accuracy of predictions is determined by the quality of base data and expert judgements.

This risk assessment included the consequences of fires and explosions, as well as toxic releases at the proposed D3 Energy facilities at various farms near Virginia in Welkom. A number of well-known sources of incident data were consulted and applied to determine the likelihood of an incident to occur.

This risk assessment was performed with the assumption that each site would be maintained to an acceptable level and that all statutory regulations would be applied. It was also assumed that the detailed engineering designs would be done by competent people and would be correctly specified for the intended duty. For example, it was assumed that the tank wall thicknesses have been correctly calculated, that vents have been sized for emergency conditions, that instrumentation and electrical components comply with the specified electrical area classification, that material of construction is compatible with the products, etc.

It is the responsibility of D3 Energy and their contractors to ensure that all engineering designs would have been completed by competent persons and that all pieces of equipment would have been installed correctly. All designs should be in full compliance with (but not limited to) the Occupational Health and Safety Act 85 of 1993 and its regulations, the National Buildings Regulations and the Buildings Standards Act 107 of 1977, as well as the local by-laws.

A number of incident scenarios were simulated, taking into account the prevailing meteorological conditions, and were described in the report.

The following installations were considered for analysis in the QRA.

5.1 Hazardous Materials

The project involves several hazardous materials associated with the well drilling, gas gathering and gas processing operations. These include:

- Compressed Natural Gas (CNG) stored at 260 bar(g), capable of producing high-energy jet fires, flash fires and vapour cloud explosions (VCEs).
- Liquefied Natural Gas (LNG) stored and transported at cryogenic temperatures (-162°C), with the potential for pool fires, flash fires and VCEs.
- Helium, stored at cryogenic conditions (-269°C), non-toxic but capable of displacing oxygen and creating asphyxiant atmospheres.
- Ammonia, used in the refrigeration system, classified as *extremely toxic* by the US EPA, with PAC-2 concentrations extending up to 3 km under worst-case conditions.
- Natural gas from wells and pipelines, capable of producing jet fires and limited flash fire / VCE effects.
- Flare gas, used for the safe disposal of off-spec gas streams, producing thermal radiation and combustion emissions.

These materials require engineered containment, emergency shutdown systems, exclusion zones, and operational controls to ensure compliance with NEMA and SANS risk management principles.

5.2 Limitations and Assumptions

The risk assessment was developed based on the information provided by the client, and its engineering suppliers. These designs are conceptual and does not include detailed designs or in some cases, insufficient information to conduct a thorough risk assessment. To this end, the results obtained in this report may lack the accuracy of a detailed engineered plant. However, the risks generated are expected to represent the facility, provided that the vessel size and inventory are not increased.

These assumptions ensure that the assessment remains precautionary and aligned with the NEMA principles of risk avoidance and minimisation.

5.3 Major Hazard Installation (MHI) Tier Classification

The MHI Regulations (2022), under Chapter 1, Chapter 2 and Chapter 3, defines the establishment tier for hazardous installations. The hazardous materials stored at the gas processing plant were evaluated by using the aggregation method prescribed in the Regulations.

The aggregated hazardous inventory is below the threshold values for all tiers. Therefore, the gas processing plant is *not* a MHI Establishment under the MHI Regulations (2022).

The gas gathering pipeline system is **not** classified as Major Hazard Establishment under Chapter 3.

5.4 Well Drilling and Gathering Pipeline

The wellfield comprises of 43 wells, including 13 new wells and 3 existing wells positioned along the Virginia Fault. These wells operate at a relatively low pressure of 50 psig, resulting in highly localised consequence distances. The modelling confirms that a catastrophic well failure would generate a vertical jet fire with a 1% fatality distance of approximately 4 m, while flash fire and vapour cloud explosion (VCE) effects are negligible. This demonstrates that well-related risks are spatially constrained and do not pose off-site fatality risks.

The 315 mm buried gathering pipeline exhibits similarly limited consequence distances. A full-bore rupture could produce a jet fire extending up to 68 m, a flash fire of 4 m, and a VCE of 9 m. These distances remain completely within the pipeline servitude, and no residential areas fall within the impact zones. Burial of the pipeline, sectional isolation valves, and leak detection systems further reduce the likelihood and consequence of such events.

Overall, the wellfield and gathering pipeline present low to medium-low residual risks, with impacts restricted to operational areas and no potential for off-site fatalities.

5.5 Gas Processing Plant

5.5.1 Compressed Natural Gas (CNG)

CNG is stored at 260 bar(g) in high-pressure vessels and transported via 22 m³ road tankers. Consequence modelling indicates that a catastrophic failure could result in flash fire distances of 206 m - 214 m and VCE distances of 110 m - 117 m. These distances may extend toward the R73 road, but remain within acceptable industrial land-use thresholds.

Engineering controls such as blast-resistant design, automatic isolation valves, and breakaway couplings significantly reduce the likelihood of such events.

Residual significance remains medium-high, driven primarily by the high-energy nature of compressed gas releases.

5.5.2 Liquefied Natural Gas (LNG)

LNG tanker failures present cryogenic and flammable hazards. A catastrophic release may generate a pool fire of 145 m, a flash fire of 206 m, and a VCE of 125 m. Flash fire effects dominate the 1% fatality boundary. Importantly, all consequence distances remain within the gas processing plant boundary, and no residential receptors fall within the impact zones. Proper cryogenic containment, ESD systems, and exclusion zones during loading ensure that LNG-related risks remain medium-high, but manageable.

5.5.3 Helium

Helium releases, although non-toxic, can displace oxygen and create asphyxiant conditions. Catastrophic failures of storage tanks or tankers produce 1% fatality distances of 44 m - 62 m, all of which remain fully confined to the plant boundary. Helium impacts therefore present medium-low residual significance, with risks mitigated through ventilation, oxygen monitoring, and cryogenic equipment integrity controls.

5.5.4 Flare System

The flare system is designed for controlled disposal of off-spec gas streams. Impacts include thermal radiation, combustion emissions, and noise, all of which remain within the plant boundary. With proper design in accordance with suitable standards, flare-related impacts are considered low-medium and do not pose off-site risks.

5.6 Impacts onto Neighbouring Properties

The results of the consequence modelling clearly demonstrate that no fatality-level impacts extend into any neighbouring residential areas under any of the credible worst-case scenarios assessed. All high-energy events associated with well failures, pipeline ruptures, CNG and LNG releases, helium releases, and flare operation remain spatially constrained within the project's operational footprint or immediate servitude.

The only endpoint that extends meaningfully off-site is the ammonia PAC-2 concentration, which may reach distances of up to 3 km under worst-case meteorological conditions. While this represents the maximum downwind distance at which individuals may experience irreversible or serious health effects, the modelling confirms that no fatalities are expected, and the PAC-3 and 1% fatality zones remain well within the plant boundary. This ensures that residential receptors are not exposed to life-threatening concentrations.

High-pressure gas systems - specifically CNG and LNG storage and tanker loading - produce flash fire and VCE distances that may extend toward the R73 road, but these remain within acceptable industrial risk thresholds and do not encroach upon sensitive land uses. The impacts are significant from an engineering perspective, but are effectively managed through exclusion zones, blast-resistant design, automatic isolation systems, and emergency shutdown procedures.

The wellfield and gathering pipeline present the lowest off-site risk profile. Consequence distances for wells (jet fire ~4 m) and pipelines (jet fire 68 m, flash fire 4 m, VCE 9 m) remain fully confined to the designated servitude, with no potential to affect residential areas or public infrastructure. Their low operating pressures and buried configuration further reduce off-site exposure.

Similarly, helium releases - although capable of creating oxygen-deficient atmospheres - produce 1% fatality distances of only 44 m - 62 m, all of which remain within the gas processing plant boundary. Helium therefore poses no off-site fatality risk.

The flare system, designed for controlled combustion of off-spec gas, generates thermal radiation, combustion emissions, and noise, but all impacts remain within the site boundary and do not affect neighbouring properties. Proper flare design in accordance with SANS 10089-2 ensures that flare-related risks remain low.

Taken together, the assessment confirms that the project does not pose unacceptable off-site risks and does not trigger fatal-flaw conditions under NEMA, the MHI Regulations (2022), or associated SANS standards. All significant impacts are either fully contained within the operational footprint or mitigated to levels consistent with industrial land-use planning requirements. The project is therefore considered environmentally viable from a risk and safety perspective.

5.7 Maximum Individual Risks

The combined site individual risk assessment integrates the full suite of consequence modelling results with the frequency analysis. Individual risk represents the probability of fatality for a hypothetical person continuously present at a specific location (24 hours per day, 365 days per year). Although this assumption overstates real-world exposure, it is intentionally conservative and widely accepted for land-use planning and regulatory compliance.

The individual risk contours shown in demonstrate a clear and favourable risk envelope around the facility. However, road crossings along the gas gathering pipeline routes require special attention during detailed design, construction and operation, and additional mitigation may be required at these locations. Each crossing should be subject to a site-specific assessment that considers traffic loading, burial depth, pipe protection, third-party interference and emergency access. Appropriate measures may include increased cover or protective sleeves, clearly marked crossing points, controlled excavation procedures, suitable isolation and leak-detection arrangements, and coordination with the relevant road authority. Crossings of higher-traffic roads should be prioritised for enhanced inspection and integrity monitoring because a loss of containment at these locations could expose road users and complicate emergency response.

Overall, the individual risk assessment confirms that no fatality-level risks extend off-site, and that all residential and public receptors remain within acceptable or trivial risk zones. **The only area requiring targeted mitigation is the LNG-related worker risk envelope, which can be reduced to acceptable levels through engineering and operational controls.**

The alternative pipeline routing, is shown in Figure 3-3. Road crossings along the gas gathering pipeline routes require special attention during detailed design, construction and operation, and additional mitigation may be required at these locations. Each crossing should be subject to a site-specific assessment that considers traffic loading, burial depth, pipe protection, third-party interference and emergency access.

Appropriate measures may include increased cover or protective sleeves, clearly marked crossing points, controlled excavation procedures, suitable isolation and leak-detection arrangements, and coordination with the relevant road authority. Crossings of higher-traffic roads should be prioritised for enhanced inspection and integrity monitoring because a loss of containment at these locations could expose road users and complicate emergency response.

Future land-use planning must continue to reference the PADHI tables to ensure compatibility with the established risk envelope.

6 RECOMMENDATIONS

RISCOM did not find any fatal flaws that would prevent the project proceeding to the detailed engineering phase of the project.

RISCOM supports the project with the following conditions:

- Compliance with all applicable statutory requirements, including the design, registration, manufacture, inspection, testing and certification of pressure equipment by competent persons in accordance with the Occupational Health and Safety Act, the Pressure Equipment Regulations and the applicable conformity-assessment requirements;
- Compliance with applicable SANS codes, i.e., SANS 10087, SANS 10089, SANS 10108, etc.;
- Incorporation of applicable guidelines or equivalent international recognised codes of good design and practice into the designs;
- Completion of a recognised process hazard analysis (such as a HAZOP study, FMEA, etc.) on the proposed facility prior to construction to ensure that design and operational hazards have been identified and that adequate mitigation is put in place;
- Application of IEC 61508 and IEC 61511 for safety instrumented systems, or equivalent recognised standards, where the process hazard analysis identifies instrumented protection, as necessary. The required safety functions, integrity targets, independence, reliability, testing, maintenance and management arrangements must be defined and maintained throughout the facility life cycle:
 - The designer must provide documented verification that the protective instrumentation is sufficient, suitably independent and reliable for the identified hazards and is correctly specified, installed, commissioned, proof-tested and maintained;
- Preparation and issue of a safety basis document during the detailed design, describing the design features, safeguards and management measures that reduce the consequences of fires, explosions, flammable or toxic releases and oxygen-deficient atmospheres. The document must be completed before construction, updated to reflect the as-built facility and retained as a controlled life-cycle document:
 - Demonstration of compliance with applicable legislation, codes and standards and recognised good engineering practice;
 - Including the listing of statutory and non-statutory inspections, giving frequency of inspections; and,
 - An independent audit of the as-built facility against the approved safety basis before commissioning, with identified deviations assessed, documented and closed out.
- Noting that codes, such as IEC 61511 can be used to achieve these requirements;
- Verification during detailed design, using complete engineering information and final maximum hazardous-material inventories, that the aggregation value remains below the lower-tier threshold and that the gas gathering pipelines do not meet the Chapter 3 criteria. The assessment and supporting calculations must be documented and reviewed by a competent process-safety practitioner. If the final design, inventories, containment arrangements or operating conditions cause any applicable threshold or Chapter 3 criterion to be met or exceeded, the MHI Regulations (2022) must be applied and an MHI risk assessment must be undertaken by an Approved Inspection Authority before construction or operation, as applicable;

- Signature of all terminal designs by a professional engineer registered in South Africa in accordance with the Professional Engineers Act, who takes responsibility for suitable designs;
- Completion of an emergency preparedness and response document for credible on-site and off-site scenarios before commissioning, with appropriate consultation with local emergency services and authorities;
- Submission of the final design safety basis and documented tier-reassessment outcome to the relevant local government authority as part of the applicable approval process. Based on the current design information, the facility falls below the lower-tier threshold and is not classified as a Major Hazard Establishment. An MHI risk assessment and registration will therefore only be required if the final design, maximum hazardous-material inventories, containment arrangements, operating conditions or pipeline design trigger an applicable threshold or Chapter 3 criterion:
 - The final verification must be based on the completed design and maximum credible inventories and must account for all engineering safeguards and mitigations.

Table of Contents

1	INTRODUCTION	1-1
1.1	Legislation	1-2
1.1.1	National Environmental Management Act (No. 107 of 1998) (NEMA) and its Regulations.....	1-2
1.1.2	The Occupational Health and Safety Act No. 85 of 1993.....	1-3
1.2	Terms of Reference	1-4
1.3	Purpose and Main Activities	1-4
1.4	Main Hazards Due to Substance and Process.....	1-4
1.5	Software	1-4
1.6	Limitations and Assumptions	1-4
2	ENVIRONMENT	2-1
2.1	General Background.....	2-1
2.2	Meteorology.....	2-2
2.2.1	Surface Winds.....	2-3
2.2.2	Precipitation and Relative Humidity	2-4
2.2.3	Temperature	2-5
2.2.4	Atmospheric Stability.....	2-6
2.2.5	Default Meteorological Value.....	2-7
3	PROJECT DESCRIPTION.....	3-1
3.1	Site.....	3-1
3.2	Process Description.....	3-3
3.2.1	Gas Composition.....	3-3
3.2.2	Well Locations.....	3-3
3.2.3	Well Drilling	3-5
3.2.4	Helium Recovery Facility and Gas Processing Plant	3-7
3.2.5	Power Generation and Network	3-9
3.2.6	Exportation Gas Pipeline.....	3-9
3.3	Establishment Tier.....	3-11
4	METHODOLOGY	4-1
4.1	Methodology Standards.....	4-1
4.2	Hazard Identification.....	4-1
4.2.1	Notifiable Substances.....	4-2
4.2.2	Substance Hazards	4-2
4.2.3	Physical Properties	4-6
4.2.4	Components Excluded from the Study	4-6
4.3	Physical and Consequence Modelling	4-7
4.3.1	Toxic Vapour Clouds.....	4-8
4.3.2	Fires.....	4-9
4.3.3	Explosions.....	4-11
4.4	Risk Analysis	4-15
4.4.1	Background.....	4-15
4.4.2	Predicted Risk.....	4-16
4.4.3	Risk Calculations.....	4-20

4.5	Quantitative Risk Assessment (QRA) Scenarios	4-25
4.5.1	Methodology	4-25
4.5.2	Scenario Selection	4-26
5	RISK ASSESSMENT	5-1
5.1	Gas Wells and Gas Gathering Pipeline.....	5-1
5.1.1	Wells and Pipeline.....	5-1
5.1.2	Consequence Modelling.....	5-1
5.2	Gas Processing Plant.....	5-5
5.2.1	The Purpose of the LNG Offloading, Storage and Vaporisation Process	5-5
5.2.2	Consequence Modelling.....	5-5
5.3	Flare.....	5-12
5.3.1	The Purpose of the Processing Unit	5-12
5.3.2	Hazardous Components.....	5-12
5.4	Combined Site Individual Risk	5-15
5.5	Risk Ranking	5-18
6	RISK REDUCTION	6-1
6.1	Mitigation.....	6-1
6.1.1	Hazardous Materials Inventory.....	6-1
6.1.2	Substitution of Hazards Materials	6-1
6.1.3	Process Hazard Analysis (PHA).....	6-1
6.1.4	Codes and Standards.....	6-2
6.1.5	Safety Instrumented Systems.....	6-2
7	IMPACT ASSESSMENT	7-1
7.1	Procedure.....	7-1
7.1.1	Determination of Significance.....	7-1
7.1.2	Impact Prioritization.....	7-5
7.2	Impact Assessment for the Potential Incidents	7-8
7.3	Impact Assessment Summary	7-10
8	CONCLUSIONS	8-1
8.1	Hazardous Materials.....	8-1
8.2	Limitations and Assumptions	8-2
8.3	Major Hazard Installation (MHI) Tier Classification	8-2
8.4	Well Drilling and Gathering Pipeline	8-2
8.5	Gas Processing Plant.....	8-2
8.5.1	Compressed Natural Gas (CNG).....	8-2
8.5.2	Liquefied Natural Gas (LNG).....	8-3
8.5.3	Helium.....	8-3
8.5.4	Flare System.....	8-3
8.6	Impacts onto Neighbouring Properties.....	8-3
8.7	Maximum Individual Risks	8-4
9	RECOMMENDATIONS.....	9-1
10	REFERENCES	10-1
11	ABBREVIATIONS AND ACRONYMS	11-1
12	APPENDIX A: SPECIALIST DECLARATION.....	12-1

13	APPENDIX B: MHI REGULATIONS (2022)	13-1
14	APPENDIX C: PADHI LAND-PLANNING TABLES	14-1
14.1	Development Type Table 1: People at Work, Parking.....	14-1
14.2	Development Type Table 2: Developments for Use by the General Public	14-2
14.3	Development Type Table 3: Developments for Use by Vulnerable People	14-6
14.4	Development Type Table 4: Very Large and Sensitive Developments.....	14-7
15	APPENDIX D: DEPARTMENT OF LABOUR CERTIFICATE	15-1
16	APPENDIX E: SANAS CERTIFICATES.....	16-1
17	APPENDIX F: MATERIAL SAFETY DATA SHEETS (MSDS).....	17-1
17.1	Liquefied Natural Gas (LNG) (CAS No.: 74-82-8).....	17-1
17.2	Natural Gas (CAS No.: 74-82-8).....	17-2
17.3	Ammonia (CAS No.: 7664-41-7).....	17-3
17.4	Helium (CAS No.: 7440-59-7).....	17-4

List of Figures

Figure 2-1:	Site locality map for the gas infrastructure, with the power plant footprints	2-1
Figure 2-2:	Seasonal wind speed as a function of wind direction at Welkom	2-3
Figure 2-3:	Atmospheric stability as a function of wind direction	2-7
Figure 3-1:	Site layout	3-2
Figure 3-2:	Area Wells and Facilities	3-4
Figure 3-3:	Alternative well locations, pipeline routing and gas-processing plant locations.....	3-5
Figure 3-4:	Process flow diagram for the helium and natural gas purification	3-7
Figure 3-5:	Layout of the helium and natural gas purification.....	3-7
Figure 4-1:	UK HSE decision-making framework.....	4-21
Figure 4-2:	Town-planning zones for pipelines	4-23
Figure 4-3:	Town-planning zones	4-24
Figure 4-4:	Airborne vapours from a loss of containment of liquefied gas stored in a pressurised vessel.....	4-26
Figure 4-5:	Event tree for an instantaneous release of a liquefied flammable gas	4-27
Figure 4-6:	Event tree for a continuous release of a liquefied flammable gas	4-27
Figure 4-7:	Event tree for a continuous release of a flammable gas	4-28
Figure 4-8:	Event tree for a continuous release of a flammable liquid.....	4-28
Figure 5-1:	Maximum extent of the flammable cloud from a failure of an individual well (side-view).....	5-2
Figure 5-2:	Side-view of the jet fire from a large release from a single well	5-3
Figure 5-3:	The maximum extent to the 1% fatality from the natural gas pipeline failure	5-4
Figure 5-4:	The extent of an expected 1% fatality in the open following large releases of helium	5-6
Figure 5-5:	The maximum extent of the impact of air concentrations of ammonia following a large release of ammonia, using the PAC-2 and PAC-3 value and the 1% fatality at the reference level of 1 m above the ground.....	5-7
Figure 5-6:	The maximum extent to the 1% fatality from a catastrophic failure of a 60 m ³ road tanker.....	5-9
Figure 5-7:	The maximum extent to the 1% fatality from a catastrophic failure of a 25 m ³ CNG storage tank.....	5-10
Figure 5-8:	The maximum extent to the 1% fatality from a catastrophic failure of a 22 m ³ CNG road tanker	5-11
Figure 5-9:	Thermal radiation that occurs during the flare operation	5-13
Figure 5-10:	Maximum extent of a flammable cloud that occurs during a flame-out flare operation	5-14
Figure 5-11:	Individual risk contours – Combined risk	5-15
Figure 5-12:	Individual risk contours – Combined risk for the alternative pipeline routing.....	5-16
Figure 5-13:	Individual risk contours – Combined risk enlarged.....	5-17
Figure 5-14:	Analysis points	5-19

List of Tables

Table 2-1:	Long-term rainfall at Welkom.....	2-4
Table 2-2:	Long-term temperatures measured at Welkom.....	2-5
Table 2-3:	Atmospheric stability classification scheme	2-6
Table 2-4:	Representative weather classes.....	2-6
Table 2-5:	Allocation of observations into the six weather classes	2-7
Table 2-6:	The default meteorological values used in the simulations, based on the local conditions.....	2-7
Table 3-1:	Gas Composition.....	3-3
Table 3-2:	Components at the Gas Processing Facility	3-8
Table 3-3:	MHI Tier Calculations	3-11
Table 4-1:	Flammable and combustible components to be stored on, produced at or delivered to site	4-5
Table 4-2:	Guideline levels for toxic and asphyxiant components.....	4-5
Table 4-3:	Representative components	4-6
Table 4-4:	Thermal radiation guidelines (BS 5980 of 1990).....	4-9
Table 4-5:	Summary of consequences of blast overpressure (Clancey 1972)	4-12
Table 4-6:	Damage caused by overpressure effects of an explosion (Stephens 1970).....	4-13
Table 4-7:	Influence of public perception of risk on acceptance of that risk, based on the POST report	4-15
Table 4-8:	Failure frequencies for atmospheric vessels.....	4-17
Table 4-9:	Failure frequencies for pressure vessels	4-17
Table 4-10:	Failure frequencies for process pipes	4-17
Table 4-11:	Probability of direct ignition for stationary installations (RIVM 2009).....	4-18
Table 4-12:	Classification of flammable substances	4-18
Table 4-13:	Land-use decision matrix.....	4-24
Table 5-1:	Scenarios modelled for the wells and pipeline	5-1
Table 5-2:	Scenarios modelled for the gas-to-power facility	5-5
Table 5-3:	Recommended design thermal radiation for personnel (API 521-2007).....	5-12
Table 5-4:	Off-site risk rankings at analysis point 1	5-18
Table 5-5:	Off-site risk rankings at analysis point 2	5-18
Table 7-1:	Criteria for Determining Impact Consequence	7-1
Table 7-2:	Probability / Likelihood Scoring	7-3
Table 7-3:	Determination of Significance	7-4
Table 7-4:	Significance Scores.....	7-4
Table 7-5:	Criteria for Determining Prioritisation	7-5
Table 7-6:	Determination of Prioritisation Factor	7-6
Table 7-7:	Final Environmental Significance Rating	7-6
Table 7-8:	Assessment of potential incidents	7-8

QUANTITATIVE RISK ASSESSMENT FOR THE PROPOSED D3 ENERGY PRODUCTION RIGHT ACTIVITIES ON VARIOUS FARMS NEAR VIRGINIA IN WELKOM, FREE STATE PROVINCE

1 INTRODUCTION

D3 Energy South Africa (Pty) Ltd (hereinafter referred to as D3 Energy) proposes to develop a gas-to-power project, including various power plants and associated infrastructure, on various farms near the City of Welkom, in the Free State Province, South Africa.

The overall project would broadly involve the following components:

- A Liquefied Natural Gas (LNG) or a Compressed Natural Gas (CNG) terminal, consisting of a berth with off-loading arms, cryogenic pipelines, storage and handling facilities and re-gasification modules;
- Gas-to-Power plant, with a 3 000 MW generation capacity;
- Gas pipelines for the transmission, distribution and reticulation of natural gas; and,
- Electricity transmission lines to evacuate electricity to the previously approved lines.

Other project related activities under the same application include the undertaking of seismic surveys and exploration drilling. The ultimate / overall proposed project will comprise of a power plant with a power generation capacity of 3 000 MW.

An EIA application has been lodged for the project.

As developers and their chosen technologies have not yet been identified, various technologically feasible and gas plant options are applied for in the EIA. The assessment presented is based on the worst-case option for each impact. The aim of this approach is to identify the envelope limits within which the project impacts will fall, and which will be acceptable to the receiving environment with implementation of mitigation measures, where relevant.

Since off-site incidents may result due to the hazards of some of the chemical components to be stored on or delivered to site, RISCOM (PTY) LTD was commissioned to conduct a quantitative risk assessment (QRA) to determine the impacts onto surrounding properties and communities as part of an environmental impact assessment (EIA).

The purpose of this report is to convey the essential details, which include a short description of the hazards, the receiving environment and the current relevant designs, as well as risks and consequences of a major incident.

1.1 Legislation

Legislation discussed in the sub-sections below is limited to the health and safety of employees and the public.

Risk assessments are conducted when required to do so by law or by companies wishing to determine the risks of the facility for other reasons, such as insurance. In South Africa, risk assessments are carried out under the legislation of two separate acts, each with different requirements. These are discussed in the sub-sections that follow.

1.1.1 National Environmental Management Act (No. 107 of 1998) (NEMA) and its Regulations

The National Environmental Management Act (NEMA) contains South Africa's principal environmental legislation. It has, as its primary objective, to make provision for cooperative governance by establishing principles for decision making on matters affecting the environment, on the formation of institutions that will promote cooperative governance, and on establishing procedures for co-ordinating environmental functions exercised by organs of state, as well as to provide for matters connected therewith (Government Gazette 1998).

Section 30 of the NEMA act deals with the control of emergency incidents where an *"incident"* is defined as an *"unexpected sudden occurrence, including a major emission, fire or explosion leading to serious danger to the public or potentially serious pollution of or detriment to the environment, whether immediate or delayed"*.

The act defines *"pollution"* as *"any change in the environment caused by:*

- (i) Substances;
- (ii) Radioactive or other waves; or,
- (iii) Noise, odours, dust or heat...

Emitted from any activity, including the storage or treatment of waste or substances, construction and the provision of services, whether engaged in by any person or an organ of state, where that change has an adverse effect on human health or wellbeing or on the composition, resilience and productivity of natural or managed ecosystems, or on materials useful to people, or will have such an effect in the future...

"Serious" is not fully defined, but would be accepted as having long lasting effects that could pose a risk to the environment or to the health of the public that is not immediately reversible.

This is similar to the definition of a MHI as defined in the Occupational Health and Safety Act (OHS Act) 85 of 1993 and the associated MHI regulations.

Section 28 of NEMA makes provision for anyone who causes pollution or degradation of the environment being made responsible for the prevention of the occurrence, continuation or re-occurrence of related impacts and for the costs of repair of the environment. In terms of the provisions under Section 28 that are stated as:

" Every person who causes, has caused or may cause significant pollution or degradation of the environment must take reasonable measures to prevent such pollution or degradation from occurring, continuing or recurring, or, in so far as such harm to the environment is authorised by law or cannot reasonably be avoided or stopped..."

1.1.2 The Occupational Health and Safety Act No. 85 of 1993

The Occupation Health and Safety Act 85 (1993) is primarily intended for the health and safety of the employees, whereas its MHI Regulations is intended for the health and safety of the public.

The OHS Act shall not apply in respect of:

- “
- a) *A mine, a mining area or any works as defined in the Minerals Act, 1991 (Act No. 50 of 1991), except in so far as that Act provides otherwise; or,*
 - b) *Any load line ship (including a ship holding a load line exemption certificate), fishing boat, sealing boat and whaling boat as defined in Section 2 (1) of the Merchant Shipping Act, 1951 (Act No. 57 of 1951), or any floating crane, whether or not such ship, boat or crane is in or out of the water within any harbour in the Republic or within the territorial waters thereof, (date of commencement of paragraph (b) to be proclaimed.), or in respect of any person present on or in any such mine, mining area, works, ship, boat or crane.*
- ”

1.1.2.1 Major Hazard Installation Regulations

Concern about the health and safety of the public has led to regulation of handling, storage and the use of industrial chemicals. On the 16th of January 1998, the Major Hazard Installation regulations were promulgated under the Occupational Health and Safety Act (Act No. 85 of 1993; hereinafter referred to as the OHS Act), with a further amendment on the 30th of July 2001.

On the 31st of January 2023, new MHI regulations were gazetted, whereby the facility would be classified based on the amount of hazardous products stored on site. The threshold values for these hazardous products are defined within the Regulations.

In accordance with the legislation, the risk assessment must be done by an approved inspection authority (AIA), which is registered with the Department of Employment and Labour and accredited by the South African Accreditation Systems (SANAS). Furthermore, the Engineering Professional Act 114 of 2000, requires all persons conducting engineering work to be registered with the Engineering Council of South Africa and may not perform work outside of their field of registration. Copies of the relevant certificates are given in Section 15 and Section 16.

1.2 Terms of Reference

The main aim of the investigation was to quantify the risks to employees, neighbours and the public with regard to the proposed D3 Energy facilities at various farms near Virginia in Welkom.

The scope of the risk assessment included:

1. Develop accidental spill and fire scenarios for the facility;
2. Using generic failure rates, determine the probability of each scenario identified, as well as potential consequences;
3. Where the consequence / risk will extend beyond the site boundary, calculate the maximum individual risk, taking into account generic failure rates, initiating events, meteorological conditions and lethality;
4. Determine and comment on the societal risk posed by the facility;
5. Recommend mitigation measures to minimise risk where required; and,
6. Identify and assess impacts, including cumulative impacts of the project.

This risk assessment is not intended to replace an MHI risk assessment nor any other legal requirement.

1.3 Purpose and Main Activities

The principal activity of the proposed D3 Energy facilities on various farms near Virginia and Welkom would be the extraction, gathering, processing and dispatch of natural gas. Gas produced from the wells would be conveyed through the underground gathering system to the central processing plant for compression or liquefaction as CNG and / or LNG.

1.4 Main Hazards Due to Substance and Process

The main hazards that would occur with a loss of containment of hazardous components at the proposed D3 Energy facilities at various farms near Virginia in Welkom include exposure to:

- Toxic vapours;
- Asphyxiant vapours;
- Thermal radiation from fires; and,
- Overpressure from explosions.

1.5 Software

Physical consequences were calculated by using Gexcon's RISKCURVES v. 13.0.2. All calculations were performed by Mr M P Oberholzer.

1.6 Limitations and Assumptions

The risk assessment was developed based on the information provided by the client, and its engineering suppliers. These designs are conceptual and does not include detailed designs or in some cases insufficient information to conduct a thorough risk assessment.

To this end, the results obtained in this report may lack the accuracy of a detailed engineered plant. However, the risks generated are expected to represent the facility, provided that the vessel size and inventory are not increased.

2 ENVIRONMENT

2.1 General Background

The proposed D3 Energy project, as shown in Figure 2-1, comprises the production wells, gas gathering pipelines, and the central gas processing plant for CNG and / or LNG production.

The originally approved exploration area is located over an area of approximately 149 377 hectares (ha), covering various farms near the City of Welkom, within the Free State Province, extending north from Theunissen, northeast towards Kroonstad, and east of Virginia and Hennenman.

D3 Energy were subsequently required to relinquish part of their ER land position during their second renewal which reduced the ER footprint to approximately 95 483 ha, a decrease of over 50 000 ha less than the originally approved area. The applicant wishes to convert a portion of their existing Exploration Right area (ER315) into a Production Right (PR). The proposed extraction and production will target helium and methane gas, and will consist of up to 43 production wells, gas gathering pipelines, a helium recovery and gas processing plant (CNG and / or LNG) and associated infrastructure. In addition, ongoing exploration activities will include drilling of up to 48 exploration wells, and 8 seismic transects with a combined length of ~62.5 km of seismic and / or audio magnetotelluric surveys. The proposed production right application area covers a total of ~14 440 hectares.

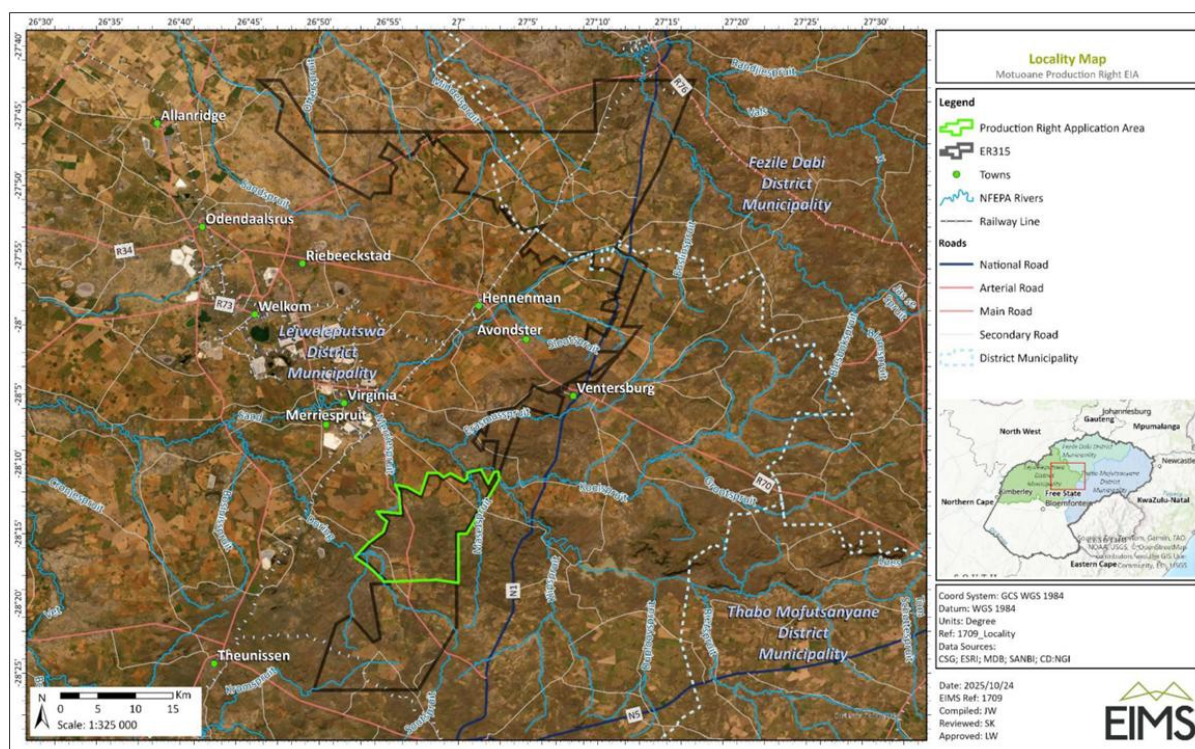


Figure 2-1: Site locality map for the gas infrastructure, with the power plant footprints

2.2 Meteorology

Meteorological mechanisms govern dispersion, transformation and eventual removal of hazardous vapours from the atmosphere. The extent to which hazardous vapours will accumulate or disperse in the atmosphere is dependent on the degree of thermal and mechanical turbulence within the earth's boundary layer.

Dispersion comprises of vertical and horizontal components of motion. The stability and the depth of the atmosphere from the surface (known as the mixing layer) define the vertical component. The horizontal dispersion of hazardous vapours in the atmospheric boundary layer is primarily a function of wind field. The wind speed determines both the distance of downwind transport and the rate of dilution as a result of stretching of the plume, where the generation of mechanical turbulence is a function of the wind speed in combination with the surface roughness. Wind direction and the variability in wind direction both determine the general path that hazardous vapours will follow and the extent of crosswind spreading.

Concentration levels of hazardous vapours therefore fluctuate in response to changes in atmospheric stability, to concurrent variations in the mixing layer depth and to shifts in the wind field.

For this report, the meteorological conditions at Welkom, was obtained from Meteoblue; https://www.meteoblue.com/en/weather/historyclimate/climatemodelled/welkom_south-africa_940909.

2.2.1 Surface Winds

The surface wind regime at Welkom (27.98° S, 26.74° E; 1376 m asl) is characterised by predominantly easterly to northeasterly flow, with secondary contributions from north-westerly and westerly directions. The wind rose in Figure 2-2 indicates that the most frequent and strongest winds occur from the ENE–NE–NNE sectors, typically ranging between 10 km/h and 20 km/h, with occasional gusts reaching 20 km/h to 30 km/h.

Calm conditions below 2 km/h are infrequent, suggesting a generally active and well-ventilated boundary layer. Southerly and southeasterly winds are minor components, occurring only sporadically throughout the year.

Overall, Welkom experiences a bidirectional wind pattern, alternating between easterly daytime flows and westerly nighttime drainage winds, typical of the Highveld plateau. This regime supports effective dispersion of surface emissions and contributes to moderate ventilation across the region.

Welkom

27.98°S, 26.74°E (1376 m asl).
Model: ERA5T.

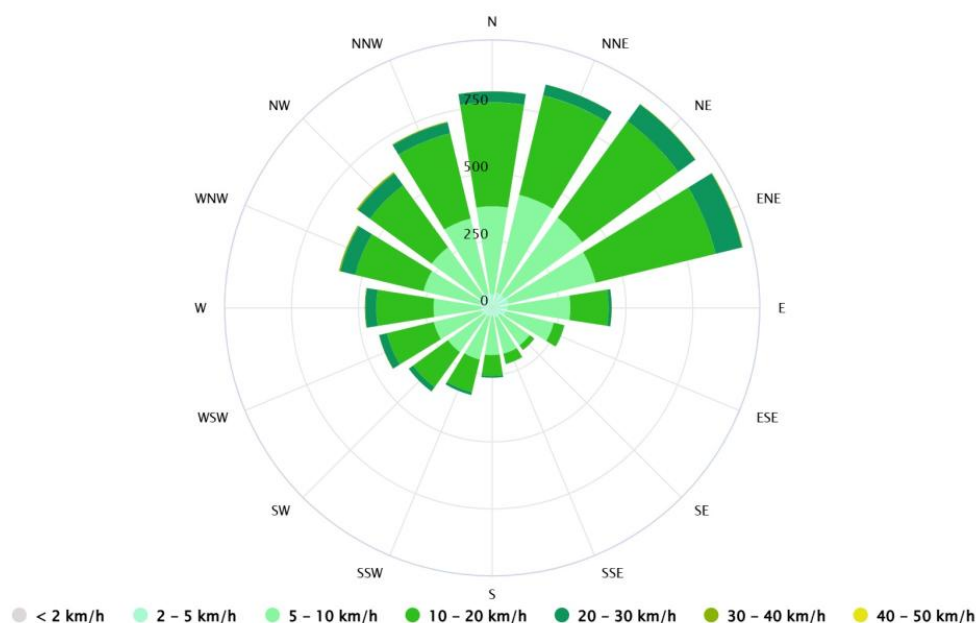


Figure 2-2: Seasonal wind speed as a function of wind direction at Welkom

2.2.2 Precipitation and Relative Humidity

The long-term rainfall and relative humidity recorded at Welkom, is given in Table 2-1.

In Welkom there is an average annual rainfall of 536 mm occurring throughout the year with no distinct winter or summer rainfall patterns.

The average relative humidity typically ranges from 31% during the day to 56% over the year.

Table 2-1: Long-term rainfall at Welkom

Month	Precipitation (mm)	Humidity %
January	97	52
February	77	54
March	61	54
April	21	56
May	21	53
June	12	53
July	7	45
August	15	37
September	16	31
October	47	36
November	69	39
December	93	47
Year	536	46.4

2.2.3 Temperature

The long-term temperatures provided at Welkom, are given in Table 2-2.

The surrounding region has a temperate climate with the average daily maximum being between 20°C and 25°C. Temperatures rarely extend below freezing, with the mean minimum average daily temperature of 13°C.

The diurnal temperature average was calculated to be 18°C, and liquid pool calculations were calculated with a temperature of 18°C.

Table 2-2: Long-term temperatures measured at Welkom

Month	Average Daily Maximum (°C)	Average Daily Minimum (°C)	Average Daily Mean (°C)
January	30	17	23.5
February	29	17	23
March	28	15	21.5
April	24	11	17.5
May	22	6	14
June	19	2	10.5
July	19	2	10.5
August	22	5	13.5
September	26	9	17.5
October	28	13	20.5
November	29	14	21.5
December	30	16	23
Year	25.5	9.7	17.6

2.2.4 Atmospheric Stability

Atmospheric stability is frequently categorised into one of six stability classes. These are briefly described in Table 2-3. The atmospheric stability, in combination with the wind speed, is important in determining the extent of a pollutant from a release. A very stable atmospheric condition, typically at night, would have a low wind speed and produce the greatest endpoint for a dense gas. Conversely, a buoyant gas would have the greatest endpoint distance at a high wind speed.

Table 2-3: Atmospheric stability classification scheme

Stability Class	Stability Classification	Description
A	Very unstable	Calm wind, clear skies, hot daytime conditions.
B	Moderately unstable	Clear skies, daytime conditions.
C	Unstable	Moderate wind, slightly overcast daytime conditions.
D	Neutral	Strong winds or cloudy days and nights.
E	Stable	Moderate wind, slightly overcast night-time conditions.
F	Very stable	Low winds, clear skies, cold night-time conditions.

Calculations for this risk assessment are calculated on the six represented weather classes covering the stability conditions of stable, neutral and unstable, as well as low and high wind speeds. In terms of the Pasquill classes, the representative conditions are given in Table 2-4.

Table 2-4: Representative weather classes

Stability Class	Wind (m/s)
B	3
D	1.5
D	5
D	9
E	5
F	1.5

Due to the absence of hourly readings for the wind speed and direction, the wind rose source was used, where hourly readings of various wind speeds at 16 cardinal directions was obtained. The yearly hours were assumed to be 50% during daytime and 50% during night-time hours. The allocation of the six weather classes, as given in Table 2-5, were then derived for the cardinal directions and is shown in Figure 2-3. The risk was then determined by using the contributions of each wind class in various wind directions.

Table 2-5: Allocation of observations into the six weather classes

Wind Speed	A	B	B/C	C	C/D	D	E	F
< 2.5 m/s	B 3 m/s			D 1.5 m/s			F 1.5 m/s	
2.5 - 6 m/s				D 5 m/s			E 5 m/s	
> 6 m/s				D 9 m/s				

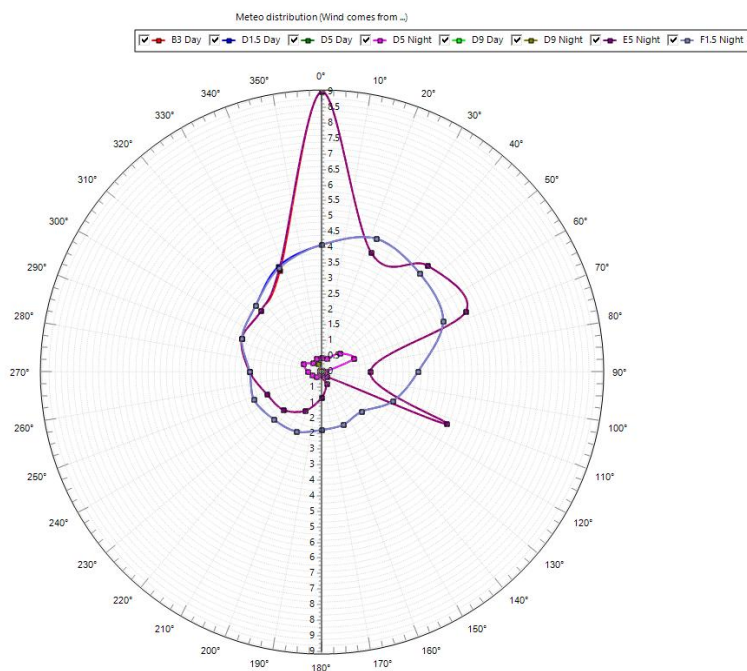


Figure 2-3: Atmospheric stability as a function of wind direction

2.2.5 Default Meteorological Value

The default meteorological values used in the simulations, based on the local conditions, are given below in Table 2-6.

Table 2-6: The default meteorological values used in the simulations, based on the local conditions

Parameter	Default Value Daytime	Default Value Night Time
Ambient temperature (°C)	25	10
Substrate/bund temperature (°C)	18	18
Water temperature (°C)	18	18
Air pressure (bar)	0.85	0.85
Humidity (%)	46	46
Fraction of a 24-hour period	0.5	0.5
Mixing height ¹	1	1

¹ Mixing height is calculated as part of the software.

3 PROJECT DESCRIPTION

3.1 Site

The layout of the power station has not been developed. However, a typical layout of the proposed power plant facility, is shown in Figure 3-1. Each module will have a natural gas supply line, gas turbines, steam turbines, transformers, a substation, switch yard, water treatment area and a back-up fuel (LO) area. The administration building will be common for the two modules.

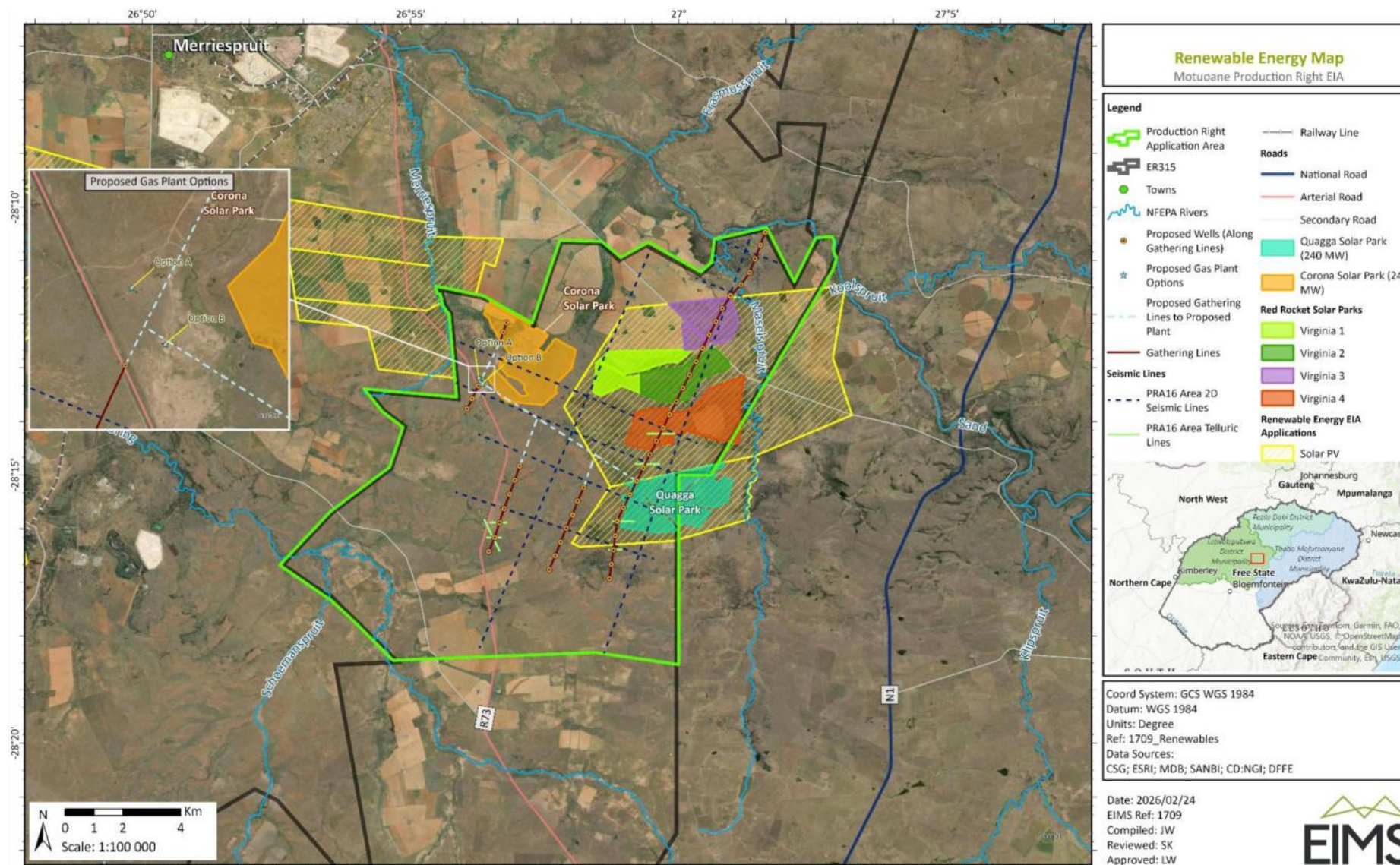


Figure 3-1: Site layout

3.2 Process Description

The proposed development of the Gas Project area will involve the following activities:

- Pre-drilling seismic and / or audio magnetotelluric surveys to optimize well locations for maximum deliverability;
- Drilling and completion of wells;
- Maintenance workovers of wells;
- Construction of gas flowline gathering systems;
- Installation of gas compression and processing facilities;
- Construction of a helium recovery facility and gas (methane) processing plant (CNG or LNG); and the,
- Construction of associated infrastructure including roads, borrow pits, communications facilities and temporary accommodation facilities, if necessary.

3.2.1 Gas Composition

The gas composition used for the Gas Project design work is shown below in Table 3-1. This is based on sample analysis taken from wells within the proposed development area.

Table 3-1: Gas Composition

Helium (%)	Methane (%)	Ethane (ppm)	Propane (ppm)	Nitrogen (%)	Carbon Dioxide (ppm)
5.6	86.5	554	>50	7.8	60

3.2.2 Well Locations

The locations of all wells and infrastructure have been chosen by using desktop studies and available information from publicly available mapping services.

All well locations, flowline gathering lines and processing plant infrastructure will be located in consultation with the landowner and will be located to minimize damage to improvements, vegetation and land. Facilities and wells will be located close to existing fence lines and tracks where practical and will not be located within close proximity to housing and major structures.

Figure 3-2 shows the proposed development locations for wells, pipelines and infrastructure. In total there are 43 well development locations that are located along known faults and close to either existing blowers or exploration wells drilled by the company. The initial development will focus on the wells located on the Virginia fault where there are 13 new well locations and 3 existing wells that will be utilised in the development.

Structure mapping has been used to position wells above the predicted gas water contact depth. This gas water contact depth assumption may change as more drilling and other geological data is gathered and may increase the number of wells in the development.

Seismic and audio magnetotelluric surveys may locate additional faults within the Gas Project and will also increase the development well numbers.

There is one central gas and helium processing plant that is connected to the production wells by gathering pipelines.

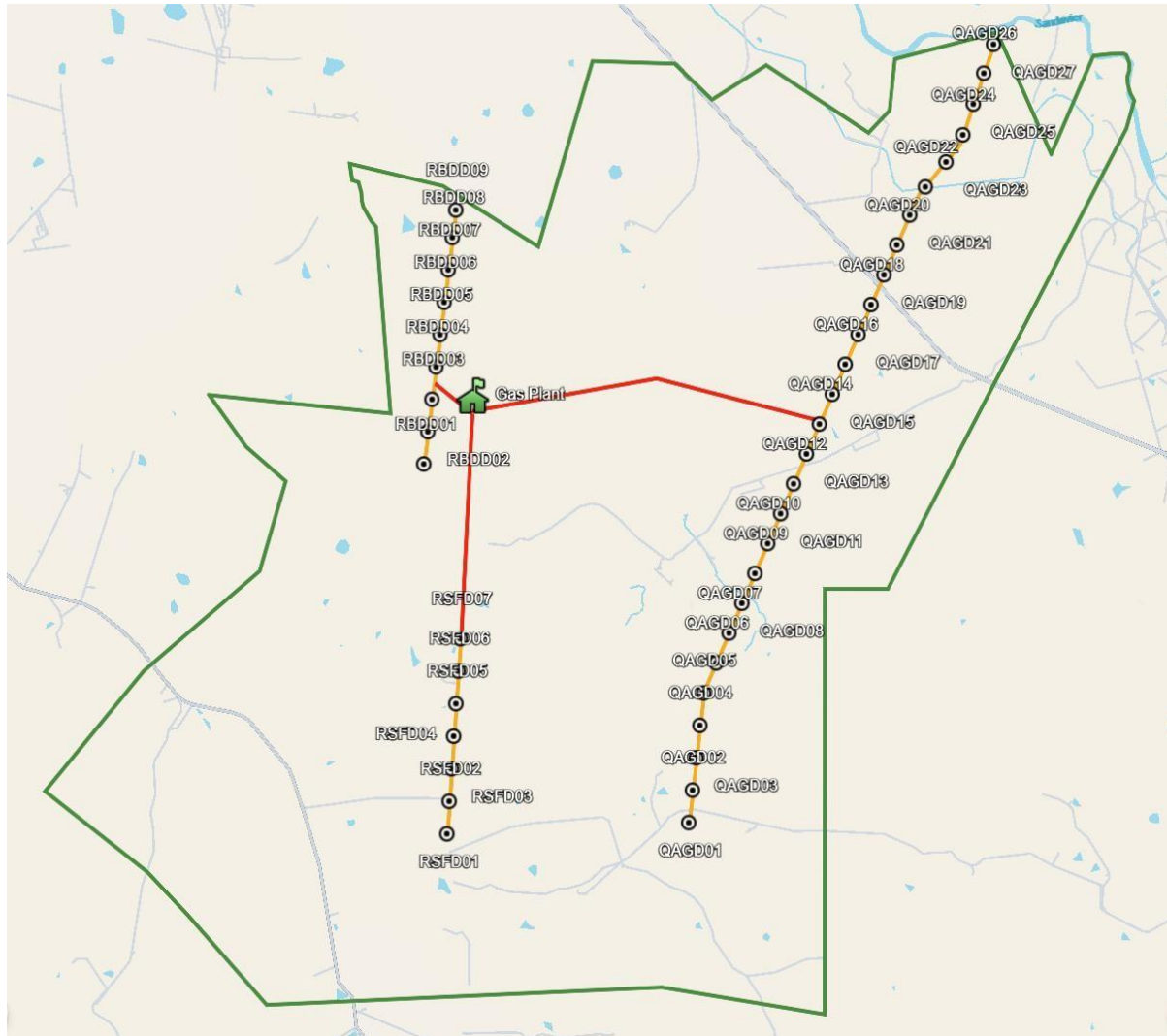


Figure 3-2: Area Wells and Facilities

Figure 3-3 shows the alternative well locations, pipeline routing and gas-processing plant locations considered for the proposed development.

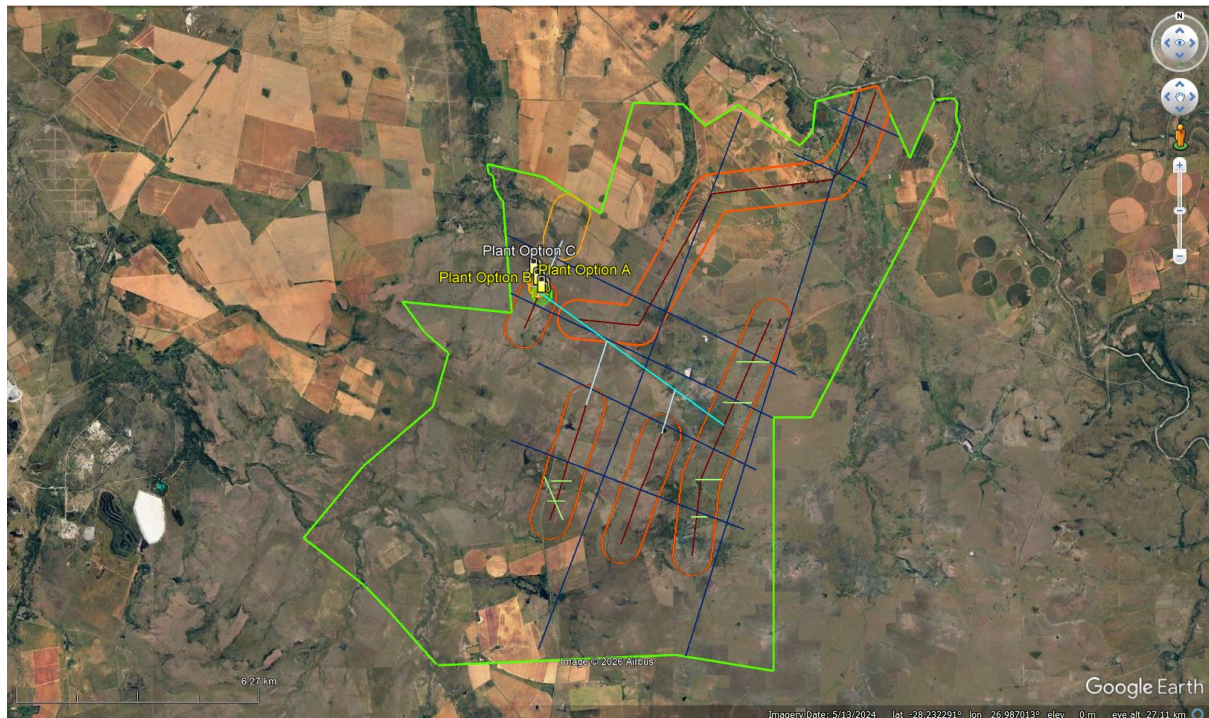


Figure 3-3: Alternative well locations, pipeline routing and gas-processing plant locations

3.2.3 Well Drilling

A development spacing of 500 m has been chosen for the wells to be drilled. This spacing has been chosen following a review of geological and reservoir properties, including well interference testing. The wells will be drilled to a total depth of approximately 500 m and will be completed open-hole in the reservoir zone. The hole diameter will mostly be 5" NB, for the hole depth.

Production casing from the surface to the base of the Karoo will be cemented to the surface to ensure wellbore integrity. Then, the well will be drilled into the Witwatersrand formation in order to encounter gas-producing fractures.

Initially, D3 Energy will log the open hole Karoo, run and set casing, then run a Casing Bond Log (CBL). Upon reaching the Total Depth (TD), D3 Energy will log the open hole beneath the casing. This logging program may evolve as drilling continues.

To the extent possible, lease construction will take place during the gathering system construction to optimize the use of earthmoving equipment and minimize impacts.

The wells will be completed as simple open hole completions, with no tubing or pumping equipment necessary.

3.2.3.1 Well Surface Facilities

The wellhead surface facilities will be simplistic in design to have a minimum footprint on the environment. As it is anticipated that there will be no liquids produced from the wells contemplated herein, there will be no need for surface equipment such as water storage and holding tanks to be located at the wellheads. The fencing surrounding the well site will be able to be modified easily to maximise the land use available for the landowner. Consideration will also be given to having the wellsite facilities located below ground level in closed chambers to further reduce the visual and environmental impacts in some areas. Water will nevertheless be required for cementing, and a drill sump will be provided within the drill pad to contain water used during drilling activities.

Instrumentation at each well location will consist of gas meters and pressure monitoring only. These instruments will be powered by replaceable lithium batteries, so eliminating the need for any instrumentation that requires gas to be emitted and therefore reducing fugitive emissions. There will also not be a requirement to have any solar panels or battery boxes on the location, thereby reducing the chance of theft or vandalism.

3.2.3.2 Gas Gathering System

The gas gathering network covers all low-pressure underground pipework from the wellhead to the compressor station or gas processing plant. It is critical in this development to keep wellhead pressures low, as this maximizes gas and helium recovery from the field. The network pipelines have been designed to have only one gas and helium processing plant within the development area to reduce the requirement for nodal compression. This will reduce the environmental footprint and keep noise emitting equipment to fewer locations. There will be provision to have field nodal compression should the actual flow rates and pressures differ from the modelling.

The preliminary conceptual gas gathering system has been designed to minimize flowline pipe lengths and pressure loss, while maintaining the required distances from landowner and environmental constraints. As discussed previously, all locations will be subjected to review once stakeholder and landowner discussions commence.

Flow modelling has been conducted to ensure that the wellhead pressures at the wells are kept to a minimum. For an assumed plant suction pressure of 25 kPa(g) (3.5 psig), the highest pressure seen at a wellhead in the network is just over 70 kPa(g) (10.0 psig).

The sizing of the high-density polyethylene pipe (HDPE) pipelines will range from 110 mm in diameter for up to 315 mm for gas spine pipelines. The pipelines will be constructed from HDPE pipe and will be designed to use the natural flow of the land contouring to reduce the need for low point drains. Where drains are required, consideration will be given to install them in underground pits to reduce visual, environmental and landowner impacts.

Table 3-2: Components at the Gas Processing Facility

Product	Quantity	Comment
LNG	45 m ³	• Road tanker: 5 Road tankers per week • Pressure: 300 kpa(g) • Temperature: -162°C
CNG	25 m ³	• Pressure: 260 bar(g) • Temperature: -35°C
	22 m ³	• Road tankers: 8 Road tankers per day • Pressure: 260 bar(g) • Temperature: -35°C
Helium	110 m ³	• Pressure: 32 kpa(g) • Temperature: -269°C
Ammonia	Not provided - Assume 4 tonnes in total	• Refrigerant
Propane	288 kg	• Refrigerant • Pressure: Not provided - Assume ambient • Temperature: Not provided - Assume ambient

3.2.4.1 Helium Recovery

The 3.0 MMSCFD capacity helium recovery facility design features include a modular-based facility that is easily moved between sites or have additional modules added, if required. The process modules include inlet compression, pre-treatment, single stage membrane separation, pressure swing absorption (PSA) boost compression, vacuum PSA purification, helium sales compression and / or liquefaction.

The process starts with the inlet reception equipment to manage the incoming process stream to the facility. After regulating the pressure to approximately 25 kPa(g), the inlet gas is compressed to achieve the necessary pressure required to operate the membrane system. The pre-treatment module provides dew point control and removal of water that would otherwise condense in the membrane systems. The treated gas then flows to the inlet of the membrane separation system.

The membrane separation system has been designed for single stage separation. The first stage separates the bulk contaminants from the crude helium permeate stream, which flows to the PSA purification unit. The retentate stream (methane) is back-pressure controlled flowing to the package limits where it will flow into the inlet of the gas CNG or LNG facility. The crude helium from the first stage permeate is compressed on route to the PSA purification package. Within the vacuum PSA module, the crude helium stream is purified to >98% within the PSA vessels before flowing to the helium sales compressor or liquefaction unit.

For gaseous helium sales, the gas compressor is designed to deliver pressure up to 200 kPa(g) to the 3-truck loading system. The manual loading system is located at the end of the helium sales gas compressor package.

If D3 Energy decides to liquify the helium gas on the project site, the helium liquefaction unit will receive purified helium from the PSA module and will deliver grade 5 helium to the liquid helium dewar at the outlet. From the liquid helium dewar, the liquid helium can be loaded into helium ISO Tank containers for shipment.

3.2.4.2 Methane Gas Recovery

The retentate stream (methane) from the helium recovery facility will flow into the inlet of either the CNG or LNG process modules.

The CNG module will compress the gas from the inlet pressure of 2 500 kPa(g) up to the 25 000 kPa(g) required pressure for NOVO tube trailers. As with the helium system, the compressed methane will flow from the module exit to the truck loading system. The manual loading system is located at the end of the helium sales gas compressor package.

The LNG module, if installed, will take the feed gas and compress it up to the pressure required by the plant. Before liquefaction, the carbon dioxide contained in the raw natural gas may need to be removed (pending design calculations), as it will freeze under the low temperature state used in the liquefaction process and block the equipment or reduce the performance of the heat exchanger. Should the carbon dioxide removal system be required, it uses an amine liquid to reduce the carbon dioxide concentration in the raw gas to an acceptable level.

The liquefaction element adopts a propane pre-cooling mixed refrigerant refrigeration process. The pre-coolant is propane, and the mixed refrigerant is nitrogen, methane, ethylene and propane components.

The purified, predominately methane gas, will be precooled by a pre-coolant before entering the cold box. Any heavy hydrocarbons in the gas stream will also freeze at low temperatures, so a heavy hydrocarbon separator is set up in the cold box to separate any condensed heavy hydrocarbons. The gas entering the cold box uses the large amount of cold released by the mixed refrigerant in the cold box to liquefy the natural gas, and the liquefied LNG is sent to the manual loading system used to fill the LNG trucks.

3.2.5 Power Generation and Network

The power supply requirements for the development will consist of:

- Auxiliary power at processing plants; and,
- Electrical-driven compressors and pumps used in the helium and methane plants.

It is planned that the power will be supplied by gas powered generators that utilise the produced gas from the plant inlet following filtration and dehydration. The system will be set up with a redundant generator with an auto changeover backup system, should a unit shutdown unexpectedly or during servicing and maintenance events. There will also be a diesel generator available for black starts when no gas supply is available.

3.2.6 Exportation Gas Pipeline

There are no transmission pipelines in the vicinity of the Gas Project area, and no pipelines are planned for this stage of the development.

3.2.6.1 Nitrogen Installation

Nitrogen is an inert gas and would be used to purge lines and equipment prior to maintenance. It is expected that nitrogen would be stored in gas cylinders or a cryogenic storage vessel or would be produced on site by removing the nitrogen from the air. This study assumes that nitrogen will be brought to site as part of maintenance, with no permanent storage.

3.2.6.2 Flare

A flare is shown in the process flow diagram and facility layout provided for this assessment (See Figure 3-4 and Figure 3-5). On that basis, a flare was included for controlled disposal of off-specification gas. The flowrate was provided as 150 m³ per day. As the flare height and pilot-fuel details were not provided, the assessment assumed a release height of 10 m above grade and no pilot-fuel requirement. These assumptions must be confirmed against the final design.

3.3 Establishment Tier

The MHI Regulations (2022), under Chapter 1, Chapter 2 and Chapter 3 defines the establishment tier. Pipelines that meet the criteria of Chapter 3 are considered a High Tier Establishment Major Hazard Installation.

Based on the current design basis and the hazardous material storage inventories presently available, the aggregated inventory falls below the lower-tier threshold, as shown in Table 3-3. The proposed D3 Energy facilities on various farms near Virginia in Welkom would therefore not be classified as a Major Hazard Establishment under the MHI Regulations (2022). This preliminary classification may change as the detailed design is developed and the final storage inventories, containment arrangements and operating conditions are confirmed, and must therefore be reassessed by using the final design information.

Table 3-3: MHI Tier Calculations

Product	UN Number	SANS 10228 Class	Inventory (t)	Aggregation Calculations			Tier Classification (t)		
				Low Hazard	Medium Hazard	High Hazard	Low Hazard	Medium Hazard	High Hazard
CNG	1971	2.1	6.70	0.670	0.134	0.034	10	50	200
Helium	1046	2.2	12.78	0.000	0.000	0.000	0	0	0
Propane	1973	2.1	0.29	0.029	0.006	0.001	10	50	200
Ammonia	1202	2.3	4.00	0.267	0.080	0.020	15	50	200
Total				0.965	0.220	0.055			

SANS 1461 (2018) / Regulatory Status: EXEMPT FROM DIRECT PIPELINE MHI REGISTRATION: Under South African statutory guidelines, localized gas gathering / collection lines operating at low pressures - specifically those below the standard high-pressure transmission threshold (typically 100 kPa(g) to 700 kPa(g) depending on local municipal bylaws) - do not independently qualify as an "MHI Major Pipeline Establishment".

4 METHODOLOGY

4.1 Methodology Standards

The methodology for this study is generally based on the South African SANS 1461 (2018) standard for scenario definitions, failure rates, risk criteria and calculation assumptions.

SANS 1461 (2018) is based on RIVM (2009) for process plants. The latter standards describe the minimum scenarios to be included in the assessment, as well as the assumptions to be used. As full compliance of SANS 1461 (2018) cannot be achieved within the NEMA legislative framework, general compliance of the aforementioned standards would be applicable and briefly described in the sections below.

4.2 Hazard Identification

The first step in any risk assessment is to identify all hazards. The merit of including a hazard for further investigation is then determined by how significant it is, normally by using a cut-off or threshold value.

Once a hazard has been identified, it is necessary to assess it in terms of the risk it presents to the employees and the neighbouring community. In principle, both the probability and the consequence should be considered but there are occasions where, if either the probability or the consequence can be shown to be sufficiently low or sufficiently high, decisions can be made based on just one factor.

During the hazard identification component of the report, the following considerations are taken into account:

- Chemical identities;
- Location of on-site installations that use, produce, process, transport or store hazardous components;
- Type and design of containers, vessels or pipelines;
- Quantity of material that could be involved in an airborne release; and the,
- Nature of the hazard most likely to accompany hazardous materials spills or releases, e.g., airborne toxic vapours or mists, fires or explosions, large quantities to be stored and certain handling conditions of processed components.

The evaluation methodology assumes that the facility will perform as designed in absence of unintended events, such as component and material failures of equipment, human errors, external events and process unknowns.

4.2.1 Notifiable Substances

The General Machinery Regulation 8 and its Schedule A on notifiable substances requires any employer who has a substance equal to or exceeding the quantity listed in the regulation to notify the divisional director. A site is classified as a Major Hazard Installation if it contains one or more notifiable substances or if the off-site risk is sufficiently high. The latter can only be determined from a quantitative risk assessment.

Methane (compressed) is listed as a notifiable substance at a threshold value of 15 t. The schedule does not specifically mention LNG. Furthermore, the storage of LNG would be in the liquid state and not compressed. To this end, LNG would not be classified as a notifiable substance.

However, if the design changes so that more than 15 t of LNG would be contained in a single container, the LNG would be classified as a notifiable substance and the facility would automatically be classified as a Major Hazard Installation.

4.2.2 Substance Hazards

All components on site were assessed for potential hazards according to the criteria discussed in this section.

4.2.2.1 Chemical Properties

A short description of bulk hazardous components to be stored on, produced at or delivered to site is given in the following subsections. The material safety data sheets (MSDSs) of the respective materials are attached in Appendix F.

- **Liquefied Natural Gas (CAS No.: 74-82-8)**

Liquefied Natural Gas (LNG) is a clear, colourless, and odorless cryogenic liquid composed primarily of methane, usually 90% or more, with small amounts of ethane, propane, butane, and nitrogen. It is created by cooling natural gas to approximately -162°C (-260°F) at atmospheric pressure, which reduces its volume to roughly 1/600th of its gaseous state. In its liquid form, LNG is non-toxic and non-corrosive. It is also non-flammable and cannot explode in liquid form because it lacks oxygen, though it becomes flammable when vaporized and mixed with air, typically within a 5% - 15% concentration range.

LNG has a liquid density ranging between 410 kg/m³ and 500 kg/m³, which is less than half the density of water, causing it to float if spilled on water. Upon release, it vaporizes rapidly. Initially, the cold vapours are heavier than air (density of about 1.8 times air), but they become buoyant and lighter than air once they warm up to approximately -110°C or warmer, at which point they rise and disperse. It has a boiling point of roughly -162°C, a freezing point of -182°C, and a high heating value of approximately 50 MJ/kg or 21,500 BTU/lb.

- **Natural Gas (CAS No.: 74-82-8)**

The composition of natural gas is primarily methane (±95% v/v), with other components including ethane, propane and nitrogen.

Given the flammable and potentially explosive nature of natural gas, fires and VCEs represent the primary hazards associated with transfer of the gas. The gas is a fire and explosion hazard when it is exposed to heat and flame. The lower explosive limit (LEL) is 5% v/v (meaning 5% gas to 95% air, measured by volume) and the higher explosive limit (HEL) is 15% v/v. In unconfined atmospheric conditions, the likelihood of an explosion is expected to be small. It is not compatible with strong oxidants and could result in fires and explosions in the presence of such materials.

It is non-toxic and would be considered as an asphyxiant only. Chronic and long-term effects are low and are not listed.

It is in the gaseous state at atmospheric temperatures and pressures. Economical transportation would require either liquefying or compressing the gas so that it would occupy less volume per weight. LNG has a low temperature of -162°C (at atmospheric pressure). The critical pressure of methane is 46 bar; compressed natural gas (CNG) would be above the critical pressure and would be a supercritical gas having a density similar to that of the liquid.

- **Ammonia (CAS No.: 7664-41-7)**

Ammonia is a colourless gas with a pungent and suffocating odour. It liquefies easily under pressure, with a normal boiling point of -33°C. Although classified as a non-flammable gas, it will burn in 16% – 25% vapour concentrations in air when exposed to open flames.

It is incompatible with certain materials. It is corrosive to copper, brass, silver, zinc and galvanized steel. Contact with strong oxidizers can result in fires and explosions. It forms explosive products when in contact with calcium hypochlorite (household) bleaches, halogens, gold, mercury and silver. Heat is generated when ammonia dissolves in water. At high temperatures, ammonia emits hydrogen and nitrogen. Products of combustion include nitrogen and water, which are harmless to life and the environment.

The effects of anhydrous ammonia upon the human body vary with the size and weight of the subject and to a lesser extent temperature and humidity.

Contact with liquid ammonia can cause frostbite. Ammonia is soluble in water, forming a corrosive liquid. It is toxic if swallowed or inhaled and can irritate or burn skin, eyes, the nose or the throat at levels as low as 35 ppm but normally at 100 ppm – 125 ppm, through inhalation or direct contact. At 700 ppm it can cause serious and permanent injury with extreme rapidity.

Upon contact with moist mucosal membranes (such as those in the skin, eyes and respiratory tract), ammonia reacts with water to form a strong alkali, ammonium hydroxide. This causes severe damage to the surface of tissues, thereby exposing more tissue to the effects of the alkali. Symptoms are rapid on contact due to the high-water solubility of ammonia and include immediate burning of the eyes, nose and throat and coughing and bronchospasm with wheezing and pulmonary oedema (fluid around the lungs).

Massive exposures can override the absorptive surface area of the upper respiratory tract and result in extensive injury to the lower airways and lung tissue.

There have been a number of major accidents involving ammonia involving storage tanks and pipelines as well as ammonia transported on trucks, railcars and ships.

The worst incident occurred in 1973 in Potchefstroom, South Africa, where a failure of an ammonia tank released approximately 39 t killing 18 people.

There have been a number of nonfatal releases of ammonia. A release of about 600 t of ammonia occurred from a pipeline in Floral, Arkansas, in 1971 and resulted in a fish kill but no injuries. In another incident, 230 t of ammonia was released from a pipeline at McPherson, Kansas, without fatalities.

- **Helium (CAS No.: 7440-59-7)**

Helium is a colourless, odourless, tasteless and non-toxic gas. It is the second lightest element and is chemically inert due to its complete valence electron shell. Helium has an extremely low boiling point of -268.9°C , making it the coldest liquefiable gas after hydrogen. It does not burn, does not support combustion, and is classified as a non-flammable, non-reactive gas.

Because of its chemical inertness, helium is compatible with most materials. It does not corrode metals, react with oxidizers, or form compounds under normal conditions. However, its very small atomic size allows it to diffuse through porous materials, elastomers, and poorly sealed systems. In high-pressure systems, rapid release of helium can cause cold-burns due to extreme Joule–Thomson cooling.

Helium poses asphyxiation hazards in confined spaces. Although non-toxic, it can displace oxygen in the air, leading to dizziness, unconsciousness, and death without warning. Inhalation of helium from cylinders or balloons can cause loss of consciousness due to oxygen deprivation. Liquid helium can cause severe frostbite on contact.

At cryogenic temperatures, helium becomes a powerful refrigerant used in superconducting magnets, MRI systems, and low-temperature research. Liquid helium expands by a factor of more than 700:1 when vaporising, creating a risk of pressure build-up and vessel rupture if not properly vented.

Helium is transported in high-pressure cylinders, tube trailers, and cryogenic tankers. Although chemically safe, mechanical failures, rapid decompression, or confined-space releases have caused several incidents globally.

A notable incident occurred in 1992 in Decatur, Alabama, where a rupture of a helium pipeline resulted in a large release. While no fatalities occurred, the sudden pressure drop caused structural damage and highlighted the risks associated with high-pressure inert gas systems. Other nonfatal helium releases have occurred in industrial gas facilities, research laboratories, and during cryogenic transfer operations. Most incidents involve asphyxiation hazards, pressure-related equipment failures, or frostbite injuries rather than chemical toxicity.

4.2.2.2 Flammable and Combustible Components

Flammable and combustible components are those that can ignite and give a number of hazardous effects, depending on the nature of the component and conditions. These effects may include pool fires, jet fires and flash fires, as well as explosions and fireballs.

The flammable and combustible components to be stored on, produced at or delivered to site, are listed in Table 4-1. These components have been analysed for fire and explosion risks.

Table 4-1: Flammable and combustible components to be stored on, produced at or delivered to site

Component	Flashpoint (°C)	Boiling Point (°C)	LFL (vol. %)	UFL (vol. %)
Natural gas (Modelled as methane)	-186	-161	5	15

Ammonia will burn in 16% to 25% vapour concentrations in air when exposed to open flames. However, due to its low reactivity, it is classified as a non-flammable gas and is only assessed on toxicity (RIVM, 2009).

4.2.2.3 Toxic and Asphyxiant Components

Toxic or asphyxiant components of interest to this study are those that could produce dispersing vapour clouds upon release into the atmosphere. These could subsequently cause harm through inhalation or absorption through the skin. Typically, the hazard posed by toxic or asphyxiant components will depend on both the concentration of the material in the air and the exposure duration.

Ammonia is considered an acutely toxic component. Helium is not considered as acutely toxic, but will act as an asphyxiant.

The acute exposure guideline level (AEGL) / emergency response planning guideline (ERPG) values, are given in Table 4-2.

Table 4-2: Guideline levels for toxic and asphyxiant components

Component	AEGL-1		AEGL-2		AEGL-3	
	mg/m ³	ppm	mg/m ³	ppm	mg/m ³	ppm
Helium	11000	66095	38000	2.28e5	65000	390000
Ammonia	20.9	30	111	160	766	1100

AEGL values correspond to a one-hour exposure.

4.2.3 Physical Properties

For this study, LNG and natural gas were modelled as pure components, as given in Table 4-3. The physical properties used in the simulations were based on the DIPPR¹ data base.

Table 4-3: Representative components

Component	Modelled as
Liquefied natural gas	Modelled as pure methane
Natural gas	Modelled as methane

4.2.4 Components Excluded from the Study

The following installations were not considered in this study, as the site inventories would be very small in comparison to the relatively large natural gas:

- Workshop gases;
- Flammable store; and,
- Laboratory reagents.

Turbine oil, lube oils and greases were excluded from the study as they have very high flashpoints making ignition extremely remote.

1 Design Institute for Physical Properties (DIPPR).

4.3 Physical and Consequence Modelling

In order to establish which impacts, follow an accident, it is first necessary to estimate the physical process of the spill (i.e., rate and size), spreading of the spill, evaporation from the spill, subsequent atmospheric dispersion of the airborne cloud and, in the case of ignition, the burning rate and resulting thermal radiation from a fire and the overpressures from an explosion.

The second step is then to estimate the consequences of a release on humans, fauna, flora and structures in terms of the significance and extent of the impact in the event of a release. The consequences could be due to toxic or asphyxiant vapours, thermal radiation or explosion overpressures. They may be described in various formats.

The simplest methodology would show a comparison of predicted concentrations, thermal radiation or overpressures to short-term guideline values.

In a different but more realistic fashion, the consequences may be determined by using a dose-response analysis. Dose-response analysis aims to relate the intensity of the phenomenon that constitutes a hazard to the degree of injury or damage that it can cause. Probit analysis is possibly the method mostly used to estimate the probability of death, hospitalisation or structural damage. The probit is a lognormal distribution and represents a measure of the percentage of the vulnerable resource that sustains injury or damage. The probability of injury or death (i.e., the risk level) is in turn estimated from this probit (risk characterisation).

Consequence modelling gives an indication of the extent of the impact for selected events and is primarily used for emergency planning. A consequence that would not cause any irreversible injuries would be considered insignificant, and no further analysis would then be required. The effects from major incidents are summarised in the following subsections.

4.3.1 Toxic Vapour Clouds

The purpose of considering vapour clouds emanating from toxic components is to identify sections of the surrounding community that may be affected by exposure or individuals in the community who may be subject to injury or death from an accidental release.

A toxic vapour cloud can occur when:

- Toxic gas is released under pressure;
- Toxic liquid spills and evaporates;
- Components combust forming toxic gases; or,
- Components react forming toxic gases.

In the case of a toxic liquefied gas, the rate of the component becoming airborne must be estimated as input for dispersion modelling. The pressure of contained liquefied gas is dependent on its temperature, and it remains liquefied due to the pressure inside the tank.

Quantification of the adverse impacts associated with a substance is made possible through a dose-response analysis and an exposure assessment. A large release of a toxic, flammable or explosive substance may result in death, nonlethal injury or irritation to humans and in damage to property. The characterisation of such impacts would be based on the calculation of downwind distances to various acute exposure guidelines.

Limits for brief exposure to potentially lethal levels are given in terms of lethal concentration and lethal dose. Lethal concentration and lethal dose are determined by tests on animals. Lethal concentration LC_{50} refers to the concentration of airborne material inhalation of which results in death of 50% of the test group. The period of inhalation exposure could be from 30 min to a few hours (normally up to 4 hrs.). Lethal dose LD_{50} refers to the quantity of material administered, either orally or by skin adsorption, which results in death of 50% of the test group.

An approach that may be adopted involves comparison of predicted concentrations to exposure guidelines. These guidelines may include the following occupational exposure limits: the threshold limit values (TLVs); the immediately dangerous to life or health (IDLH) values; or, the acute exposure guideline level (AEGL) values.

AEGL values were developed by the US Environmental Protection Agency (EPA) and are defined as the maximum concentrations that individuals could be exposed to for a period of one hour before certain health effects would occur in sensitive populations. In the event that AEGL values are not yet available for a particular component, emergency response planning guideline (ERPG) values or temporary emergency exposure limits (TEELs) could be used.

This study refers to the PAC values for the assessing of emergency response plans and LC_1 (1% fatality based on inhaled dosages derived from probit values) for determining the significance and extent off-site impacts. In this report all PAC values are based on one hour.

4.3.2 Fires

Combustible and flammable components within their flammable limits may ignite and burn if exposed to an ignition source of sufficient energy. On process plants, releases with ignition normally occur as a result of a leakage or spillage. Depending on the physical properties of the component and the operating parameters, combustion may take on a number of forms, such as pool fires, jet fires, flash fires and so forth.

4.3.2.1 Thermal Radiation

The effect of thermal radiation is very dependent on the type of fire and duration of exposure. Certain codes, such as the American Petroleum Institute API 520 and API 2000 codes, suggest values for the maximum heat absorbed by vessels to facilitate adequate relief designs in order to prevent failure of the vessel. Other codes, such as API 510 and the British Standards BS 5980 code, give guidelines for the maximum thermal radiation intensity and act as a guide to equipment layout, as shown in Table 4-4.

The effect of thermal radiation on human health has been widely studied, relating to the injuries to the time and the intensity of the exposure.

Table 4-4: Thermal radiation guidelines (BS 5980 of 1990)

Thermal Radiation Intensity (kW/m ²)	Limit
1.5	Will cause no discomfort for long exposure
2.1	Sufficient to cause pain if unable to reach cover within 40 seconds
4.5	Sufficient to cause pain if unable to reach cover within 20 seconds
12.5	Minimum energy required for piloted ignition of wood and melting of plastic tubing
25	Minimum energy required to ignite wood at indefinitely long exposures
37.5	Sufficient to cause serious damage to process equipment

For pool fires, jet fires and flash fires CPR 18E (Purple Book; 1999) suggests that the following thermal radiation levels should be reported, at the reference level of 1 m above the grade:

- 4 kW/m², the level that glass can withstand, preventing the fire entering a building, and that should be used for emergency planning;
- 10 kW/m², the level that represents the 1% fatality for 20 seconds of unprotected exposure and at which plastic and wood may start to burn, transferring the fire to other areas; and,
- 35 kW/m², the level at which spontaneous ignition of hair and clothing occurs, with an assumed 100% fatality, and at which initial damage to steel may occur.

4.3.2.2 Bund and Pool Fires

Pool fires, being either tank or bund fires, consist of large volumes of flammable material, at atmospheric pressure, burning in an open space. The flammable material will be consumed at the burning rate, depending on factors including the prevailing winds. During combustion, heat will be released in the form of thermal radiation. Temperatures close to the flame centre will be high, but will reduce rapidly to tolerable temperatures over a relatively short distance. Any plant building or persons close to the fire or within the intolerable zone will experience burn damage, with the severity depending on the distance from the fire and the time exposed to the heat of the fire.

In the event of a pool fire, the flames will tilt according to the wind speed and direction. The flame length and tilt angle affect the distance of thermal radiation generated.

4.3.2.3 Jet Fires

Jet fires occur when a flammable component is released with a high exit velocity ignites.

In process industries, this may be due to design (such as flares) or due to accidental releases. Ejection of a flammable component from a vessel, pipe or pipe flange may give rise to a jet fire and in some instances, the jet flame could have substantial 'reach'.

Depending on the wind speed, the flame may tilt and impinge on other pipelines, equipment or structures. The thermal radiation from these fires may cause injury to people or damage equipment some distance away from the source of the flame.

4.3.2.4 Flash Fires

A loss of containment of a flammable component may mix with air, forming a flammable mixture. The flammable cloud would be defined by the lower flammable limit (LFL) and the upper flammable limit (UFL). The extent of the flammable cloud would depend on the quantity of the released and mixed component, physical properties of the released component, wind speed and weather stability. An ignition within a flammable cloud can result in an explosion if the front is propagated by pressure. If the front is propagated by heat, then the fire moves across the flammable cloud at the flame velocity and is called a flash fire. Flash fires are characterised by low overpressure, and injuries are caused by thermal radiation. The effects of overpressures due to an exploding cloud are covered in the subsection dealing with vapour cloud explosions (VCEs).

A flash fire would extend to the lower flammable limit; however, due to the formation of pockets, it could extend beyond this limit to the point defined as the $\frac{1}{2}$ LFL. It is assumed that people within the flash fire would experience lethal injuries, while people outside of the flash fire would remain unharmed. The $\frac{1}{2}$ LFL is used for emergency planning to evacuate people to a safe distance in the event of a release.

4.3.3 Explosions

The concentration of a flammable component would decrease from the point of release to below the lower explosive limits (LEL), at which concentration the component can no longer ignite. The sudden detonation of an explosive mass would cause overpressures that could result in injury or damage to property.

Such an explosion may give rise to any of the following effects:

- Blast damage;
- Thermal damage;
- Missile damage;
- Ground tremors;
- Crater formation; or,
- Personal injury.

Obviously, the nature of these effects depends on the pressure waves and the proximity to the actual explosion. Of concern in this investigation are the 'far distance effects', such as limited structural damage and the breakage of windows, rather than crater formations.

Table 4-5 and Table 4-6 give a more detailed summary of the damage produced by an explosion due to various overpressures.

CPR 18E (Purple Book; 1999) suggests that the following overpressures should be determined:

- 0.03 bar overpressure, corresponding to the critical overpressure causing windows to break;
- 0.1 bar overpressure, corresponding to 10% of the houses being severely damaged and a probability of death indoors equal to 0.025:
 - No lethal effects are expected below the 0.1 bar overpressure on unprotected people in the open;
- 0.3 bar overpressure, corresponding to structures being severely damaged and a probability of death equal to 1.0 for unprotected people in the open; and,
- 0.7 bar overpressure, corresponding to an almost entire destruction of buildings and 100% fatality for people in the open.

Table 4-5: Summary of consequences of blast overpressure (Clancey 1972)

Pressure (Gauge)		Damage
Psi	kPa	
0.02	0.138	Annoying noise (137 dB), if of low frequency (10 – 15 Hz)
0.03	0.207	Occasional breaking of large glass windows already under strain
0.04	0.276	Loud noise (143 dB); sonic boom glass failure
0.1	0.69	Breakage of small under strain windows
0.15	1.035	Typical pressure for glass failure
0.3	2.07	'Safe distance' (probability 0.95; no serious damage beyond this value); missile limit; some damage to house ceilings; 10% window glass broken
0.4	2.76	Limited minor structural damage
0.5–1.0	3.45–6.9	Large and small windows usually shattered; occasional damage to window frames
0.7	4.83	Minor damage to house structures
1.0	6.9	Partial demolition of houses, made uninhabitable
1.0–2.0	6.9–13.8	Corrugated asbestos shattered; corrugated steel or aluminium panels, fastenings fail, followed by buckling; wood panels (standard housing) fastenings fail, panels blown in
1.3	8.97	Steel frame of clad building slightly distorted
2.0	13.8	Partial collapse of walls and roofs of houses
2.0–3.0	13.8–20.7	Concrete or cinderblock walls (not reinforced) shattered
2.3	15.87	Lower limit of serious structural damage
2.5	17.25	50% destruction of brickwork of house
3.0	20.7	Heavy machines (1.4 t) in industrial building suffered little damage; steel frame building distorted and pulled away from foundations
3.0–4.0	20.7–27.6	Frameless, self-framing steel panel building demolished
4.0	27.6	Cladding of light industrial buildings demolished
5.0	34.5	Wooden utilities poles (telegraph, etc.) snapped; tall hydraulic press (18 t) in building slightly damaged
5.0–7.0	34.5–48.3	Nearly complete destruction of houses
7.0	48.3	Loaded train wagons overturned
7.0–8.0	48.3–55.2	Brick panels (20 – 30 cm) not reinforced fail by shearing or flexure
9.0	62.1	Loaded train boxcars completely demolished
10.0	69.0	Probable total destruction buildings; heavy (3 t) machine tools moved and badly damaged; very heavy (12 000 lb. / 5443 kg) machine tools survived
300	2070	Limit of crater lip

Table 4-6: Damage caused by overpressure effects of an explosion (Stephens 1970)

Equipment	Overpressure (psi)																									
	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5	7	7.5	8	8.5	9	9.5	10	12	14	16	18	20	
Control house steel roof	A	C	V				N																			
Control house concrete roof	A	E	P	D			N																			
Cooling tower	B			F			O																			
Tank: cone roof		D				K							U													
Instrument cubicle			A			LM						T														
Fire heater				G	I					T																
Reactor: chemical				A				I				P						T								
Filter				H					F									V			T					
Regenerator						I				IP					T											
Tank: floating roof						K							U												D	
Reactor: cracking							I							I							T					
Pine supports							P					SO														
Utilities: gas meter									Q																	
Utilities: electric transformer									H					I						T						
Electric motor										H								I							V	
Blower										Q										T						
Fractionation column											R			T												
Pressure vessel horizontal												PI						T								
Utilities: gas regulator												I								MQ						
Extraction column													I							V	T					
Steam turbine															I						M	S			V	
Heat exchanger															I			T								
Tank sphere																I						I	T			
Pressure vessel vertical																					I	T				
Pump																					I		Y			

A

B

C

D

E

F

G

H

I

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K

L

M

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O

P

Q

R

S

T

U

V

Windows and gauges break

Louvers fall at 0.3–0.5 psi

Switchgear is damaged from roof collapse

Roof collapses

Instruments are damaged

Inner parts are damaged

Bracket cracks

Debris-missile damage occurs

Unit moves and pipes break

Bracing fails

Unit uplifts (half filled)

Power lines are severed

Controls are damaged

Block wall fails

Frame collapses

Frame deforms

Case is damaged

Frame cracks

Piping breaks

Unit overturns or is destroyed

Unit uplifts (0.9 filled)

Unit moves on foundations

- A Windows and gauges break
- B Louvers fall at 0.3–0.5 psi
- C Switchgear is damaged from roof collapse
- D Roof collapses
- E Instruments are damaged
- F Inner parts are damaged
- G Bracket cracks
- H Debris-missile damage occurs
- I Unit moves and pipes break
- J Bracing fails
- K Unit uplifts (half filled)
- L Power lines are severed
- M Controls are damaged
- N Block wall fails
- O Frame collapses
- P Frame deforms
- Q Case is damaged
- R Frame cracks
- S Piping breaks
- T Unit overturns or is destroyed
- U Unit uplifts (0.9 filled)
- V Unit moves on foundations

4.3.3.1 Vapour Cloud Explosions (VCEs)

The release of a flammable component into the atmosphere could result in formation of a flash fire, as described in the subsection on flash fires, or a vapour cloud explosion (VCE). In the case of a VCE, an ignited vapour cloud between the higher explosive limits (HEL) and the lower explosive limit (LEL) could form a fireball with overpressures that could result in injury or damage to property.

4.3.3.2 Boiling Liquid Expanding Vapour Explosions (BLEVEs)

A boiling liquid expanding vapour explosion (BLEVE) can occur when a flame impinges on a pressure cylinder, particularly in the vapour space region where cooling by evaporation of the contained material does not occur; the cylinder shell would weaken and rupture with a total loss of the contents, and the issuing mass of material would burn as a massive fireball.

The major consequences of a BLEVE are intense thermal radiation from the fireball, a blast wave and propelled fragments from the shattered vessel. These fragments may be projected to considerable distances. Analyses of the travel range of fragment missiles from a number of BLEVEs suggest that the majority land within 700 m from the incident may be affected. A blast wave from a BLEVE is fairly localised, but can cause significant damage to immediate equipment.

A BLEVE occurs sometime after the vessel has been engulfed in flames. Should an incident occur, that could result in a BLEVE, people should be evacuated to beyond the 1% fatality line.

4.4 Risk Analysis

4.4.1 Background

It is important to understand the difference between a hazard and a risk.

A hazard is anything that has the potential to cause damage to life, property and the environment. Furthermore, it has constant parameters (like those of petrol, chlorine, ammonia, etc.) that pose the same hazard wherever present.

On the other hand, a risk is the probability that a hazard will actually cause damage and goes along with how severe that damage will be (consequence). A risk is therefore the probability that a hazard will manifest itself. For instance, the risks of a chemical accident or spill depend upon the amount present, the process the chemical is used in, the design and safety features of its container, the exposure, the prevailing environmental and weather conditions and so on.

Risk analysis consists of a judgement of probability based on local atmospheric conditions, generic failure rates and severity of consequences, based on the best available technological information.

Risks form an inherent part of modern life. Some risks are readily accepted on a day-to-day basis, while certain hazards attract headlines even when the risk is much smaller, particularly in the field of environmental protection and health. For instance, the risk of one-in-ten-thousand chance of death per year associated with driving a car is acceptable to most people, whereas the much lower risks associated with nuclear facilities (one-in-ten-million chance of death per year) are deemed unacceptable.

A report by the British Parliamentary Office of Science and Technology (POST), entitled 'Safety in Numbers? Risk Assessment and Environmental Protection', explains how public perception of risk is influenced by a number of factors in addition to the actual size of the risk. These factors were summarised as follows in Table 4-7.

Table 4-7: Influence of public perception of risk on acceptance of that risk, based on the POST report

Control	People are more willing to accept risks they impose upon themselves or they consider to be 'natural' than to have risks imposed upon them.
Dread and Scale of Impact	Fear is greatest where the consequences of a risk are likely to be catastrophic rather than spread over time.
Familiarity	People appear more willing to accept risks that are familiar rather than new risks.
Timing	Risks seem to be more acceptable if the consequences are immediate or short term, rather than if they are delayed (especially if they might affect future generations).
Social Amplification and Attenuation	Concern can be increased because of media coverage, graphic depiction of events or reduced by economic hardship.
Trust	A key factor is how far the public trusts regulators, policy makers or industry; if these bodies are open and accountable (being honest as well as admitting mistakes and limitations and taking account of differing views without disregarding them as emotive or irrational), then the public is more likely consider them credible.

A risk assessment should be seen as an important component of ongoing preventative action, aimed at minimising or hopefully avoiding accidents. Reassessments of risks should therefore follow at regular intervals and after any changes that could alter the nature of the hazard, so contributing to an overall prevention programme and emergency response plan of the facility. Risks should be ranked with decreasing severity and the top risks reduced to acceptable levels.

Procedures for predictive hazard evaluation have been developed for the analysis of processes when evaluating very low probability accidents with very high consequences (for which there is little or no experience), as well as more likely releases with fewer consequences (for which there may be more information available). These addresses both the probability of an accident, as well as the magnitude and nature of undesirable consequences of that accident. A risk is usually defined as some simple function of both the probability and consequence.

4.4.2 Predicted Risk

Physical and consequence modelling addresses the impact of a release of a hazardous component without taking into account the probability of occurrence. This merely illustrates the significance and the extent of the impact in the event of a release. Modelling should also analyse cascading or knock-on effects due to incidents in the facility and the surrounding industries and suburbs.

During a risk analysis, the likelihood of various incidents is assessed, the consequences calculated and finally the risk for the facility is determined.

4.4.2.1 Generic Equipment Failure Scenarios

Given the broad scope of this study and the limited availability of detailed information, the analysis included only major equipment failures. Pump / compressor and transport scenarios, such as road tanker failures were not included due to their effects likely being surpassed by those of the larger vessels on-site. Unless otherwise stated, analysis was completed by using published failure rate data (RIVM 2009). Equipment failures can occur in tanks, pipelines and other items handling hazardous chemical components. These failures may result in the:

- Release of combustible, flammable and explosive components with fires or explosions upon ignition; or the,
- Release of toxic or asphyxiant components.

4.4.2.2 Storage Vessels

Scenarios involving storage vessels can include catastrophic failures that would lead to leakage into the bund with a possible bund fire. The fracture of a nozzle or transfer pipeline could also result in leakage into the bund.

Typical failure frequencies for atmospheric and pressure vessels are listed, respectively, in Table 4-8 and in Table 4-9.

Table 4-8: Failure frequencies for atmospheric vessels

Event	Leak Frequency (per item per year)
Small leaks	1×10^{-4}
Severe leaks	3×10^{-5}
Catastrophic failure	5×10^{-6}

Table 4-9: Failure frequencies for pressure vessels

Event	Failure Frequency (per item per year)
Small leaks	1×10^{-5}
Severe leaks	5×10^{-7}
Catastrophic failure	5×10^{-7}

4.4.2.3 Process Piping

Piping may fail as a result of corrosion, erosion, mechanical impact damage, pressure surge (water hammer) or operation outside the design limitations for pressure and temperature. Failures caused by corrosion and erosion usually result in small leaks, which are easily detected and corrected quickly. For significant failures, the leak duration may be from 10 to 30 minutes before detection.

Generic data for leak frequency for process piping is generally expressed in terms of the cumulative total failure rate per year for a 10 m section of pipe for each pipe diameter. Furthermore, failure frequency normally decreases when increasing the pipe diameter. Scenarios and failure frequencies for a pipeline apply to pipelines with connections, such as flanges, welds and valves.

The failure data given in Table 4-10 represents the total failure rate, incorporating all failures of whatever size and due to all probable causes. These frequencies are based on an assumed environment where no excessive vibration, corrosion, erosion or thermal cyclic stresses are expected. For incidents causing significant leaks (such as corrosion), the failure rate will be increased by a factor of 10.

Table 4-10: Failure frequencies for process pipes

Description	Frequencies of Loss of Containment for Process Pipes (per meter per year)	
	Full Bore Rupture	Leak
Nominal diameter < 75 mm	1×10^{-6}	5×10^{-6}
75 mm < nominal diameter < 150 mm	3×10^{-7}	2×10^{-6}
Nominal diameter > 150 mm	1×10^{-7}	5×10^{-7}

4.4.2.4 Ignition Probability of Flammable Gases and Liquids

The estimation of the probability of an ignition is a key step in assessment of risk for installations where flammable liquids or gases are stored. There is a reasonable amount of data available relating to the characteristics of ignition sources and the effects of the release type and the location.

The probability of ignition for stationary installations is given in Table 4-11 (along with classification of flammable substances in Table 4-12). These can be replaced with ignition probabilities related to surrounding activities. For example, the probability of a fire from a flammable release at an open flame would increase to a value of 1.

Table 4-11: Probability of direct ignition for stationary installations (RIVM 2009)

Substance Category	Source-Term Continuous	Source-Term Instantaneous	Probability of Direct Ignition
Category 0 Average to high reactivity	< 10 kg/s	< 1000 kg	0.2
	10 – 100 kg/s	1000 – 10 000 kg	0.5
	> 100 kg/s	> 10 000 kg	0.7
Category 0 Low reactivity	< 10 kg/s	< 1000 kg	0.02
	10 – 100 kg/s	1000 – 10 000 kg	0.04
	> 100 kg/s	> 10 000 kg	0.09
Category 1	All flow rates	All quantities	0.065
Category 2	All flow rates	All quantities	0.0043 ¹
Category 3 Category 4	All flow rates	All quantities	0

Table 4-12: Classification of flammable substances

Substance Category	Description	Limits
Category 0	Extremely flammable	Liquids, substances and preparations that have a flashpoint lower than 0°C and a boiling point (or the start of the boiling range) less than or equal to 35°C Gaseous substances and preparations that may ignite at normal temperature and pressure when exposed to air
Category 1	Highly flammable	Liquids, substances and preparations that have a flashpoint of below 21°C
Category 2	Flammable	Liquids, substances and preparations that have a flashpoint equal to 21°C and less than 55°C
Category 3		Liquids, substances and preparations that have a flashpoint greater than 55°C and less than or equal to 100°C
Category 4		Liquids, substances and preparations that have a flashpoint greater than 100°C

¹ This value is taken from the CPR 18E (Purple Book; 1999). RIVM (2009) gives the value of a delayed ignition as zero. RISCO (PTY) LTD believes that the CPR 18E is more appropriate for warmer climates and is a conservative value.

Note:

Methane is classified as an unreactive gas. As such, the pipeline probability was equal to the typical overall probabilities for Natural Gas, used by HSE (IGEM/TD/2 (2012)), as follows:

- Immediate ignition resulting in a fireball followed by jet fire: 0.25;
- Delayed ignition resulting in a jet fire: 0.1875; or,
- No ignition: 0.5625.

4.4.3 Risk Calculations

4.4.3.1 Maximum Individual Risk Parameter

Standard individual risk parameters include: average individual risk; weighted individual risk; maximum individual risk; and, the fatal accident rate. The lattermost parameter is more applicable to occupational exposures.

Only the maximum individual risk (MIR) parameter will be used in this assessment. For this parameter, the frequency of fatality is calculated for an individual who is presumed to be present at a specified location. This parameter (defined as the consequence of an event multiplied by the likelihood of the event) is not dependent on knowledge of populations at risk. So, it is an easier parameter to use in the predictive mode than the average individual risk or weighted individual risk. The unit of measure is the risk of fatality per person per year.

4.4.3.2 Acceptable Risks

The next step, after having characterised a risk and obtained a risk level, is to recommend whether the outcome is acceptable.

In contrast to the employees at a facility, who may be assumed to be healthy, the adopted exposure assessment applies to an average population group that also includes sensitive subpopulations. Sensitive subpopulation groups are those people that for reasons of age or medical condition have a greater than normal response to contaminants. Health guidelines and standards used to establish risk normally incorporate safety factors that addresses this group.

Among the most difficult tasks of risk characterisation is the definition of acceptable risk. In an attempt to account for risks in a manner similar to those used in everyday life, the UK Health and Safety Executive (HSE) developed the risk ALARP triangle. Applying the triangle involves deciding:

- Whether a risk is so high that something must be done about it;
- Whether the risk is or has been made so small that no further pre-cautions are necessary; or,
- If a risk falls between these two states so that it has been reduced to levels as low as reasonably practicable (ALARP).

This is illustrated in Figure 4-1.

ALARP stands for 'as low as reasonably practicable'. As used in the UK, it is the region between that which is intolerable, at 1×10^{-4} per year, and that which is broadly acceptable, at 1×10^{-6} per year. A further lower level of risk, at 3×10^{-7} per year, is applied to either vulnerable or very large populations for land-use planning.

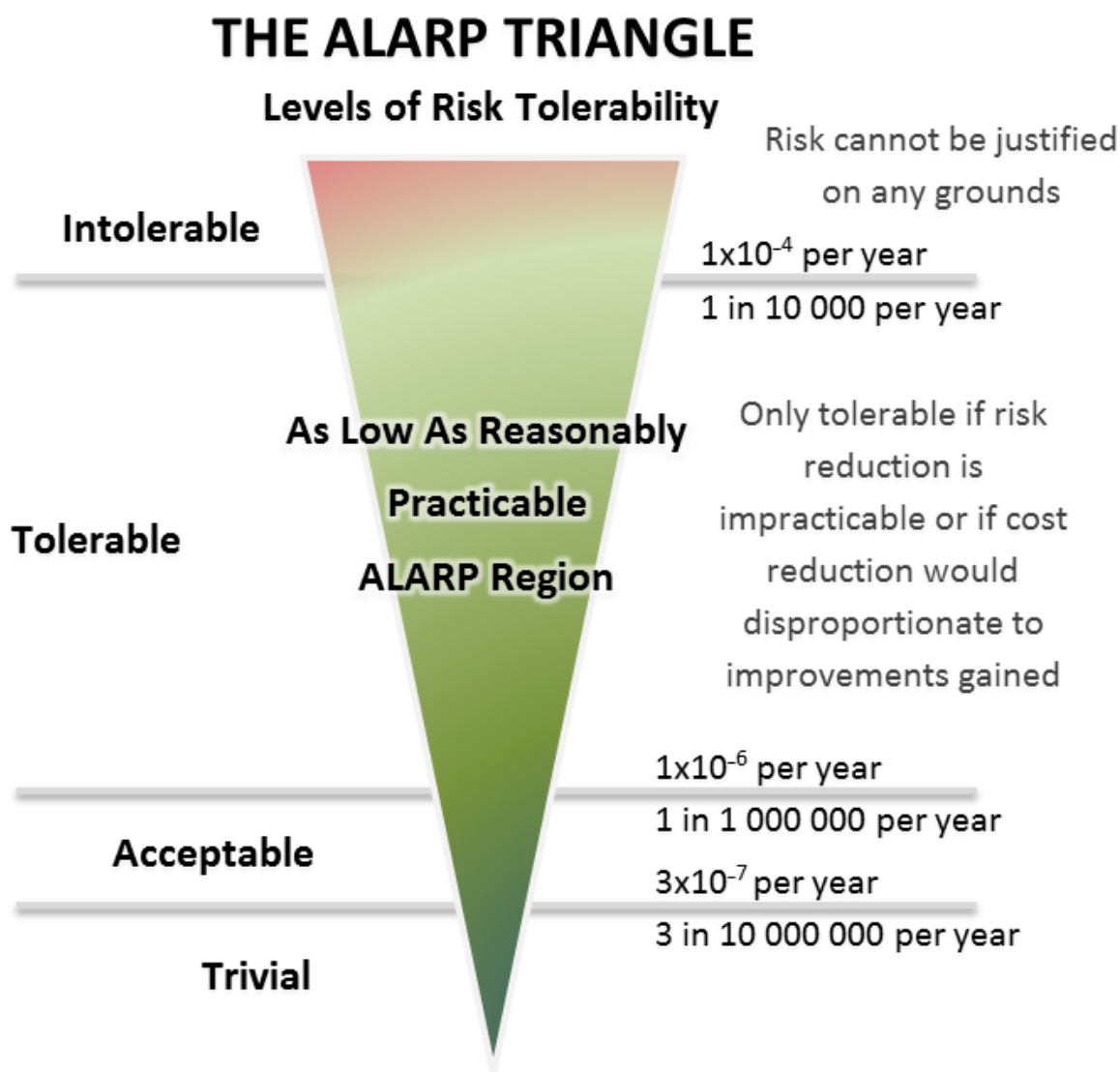


Figure 4-1: UK HSE decision-making framework

It should be emphasised that the risks considered acceptable to workers are different to those considered acceptable to the public. This is due to the fact that workers have personal protection equipment (PPE), are aware of the hazards, are sufficiently mobile to evade or escape the hazards and receive training in preventing injuries.

The HSE (UK) gives more detail on the word practicable in the following statement:

“ *In essence, making sure a risk has been reduced to ALARP is about weighing the risk against the sacrifice needed to further reduce it. The decision is weighted in favour of health and safety because the presumption is that the duty-holder should implement the risk reduction measure. To avoid having to make this sacrifice, the duty-holder must be able to show that it would be grossly disproportionate to the benefits of risk reduction that would be achieved. Thus, the process is not one of balancing the costs and benefits of measures but, rather, of adopting measures except where they are ruled out because they involve grossly disproportionate sacrifices. Extreme examples might be:*

- *To spend £1m to prevent five staff members suffering bruised knees is obviously grossly disproportionate; but,*
- *To spend £1m to prevent a major explosion capable of killing 150 people is obviously proportionate.*

Proving ALARP means that if the risks are lower than 1×10^{-4} fatalities per person per year, it can be demonstrated that there would be no more benefit from further mitigation, sometimes using cost benefit analysis. “

4.4.3.3 Land Planning

There are no legislative land-planning guidelines in South Africa and in many parts of the world. Further to this, land-planning guidelines vary from one country to another, and thus it is not easy to benchmark the results of this study to international criteria. In this instance, RISCOM would only advise on applicable land planning and would require governmental authorities to make the final decisions.

Land zoning applied in this study follows the HSE (UK) approach of defining the area affected into three zones, consistent to the ALARP approach (HSE 2011).

The three zones are defined as follows:

- The inner zone is enclosed by the risk of 1×10^{-5} fatalities per person per year isopleth;
- The middle zone is enclosed by the risk of 1×10^{-5} fatalities per person per year and the risk of 1×10^{-6} fatalities per person per year isopleths; and,
- The outer zone is enclosed by the risk 1×10^{-6} fatalities per person per year and the risk of 3×10^{-7} fatalities per person per year isopleths.

The risks decrease from the inner zone to the outer zone, as shown in Figure 4-2 and Figure 4-3.

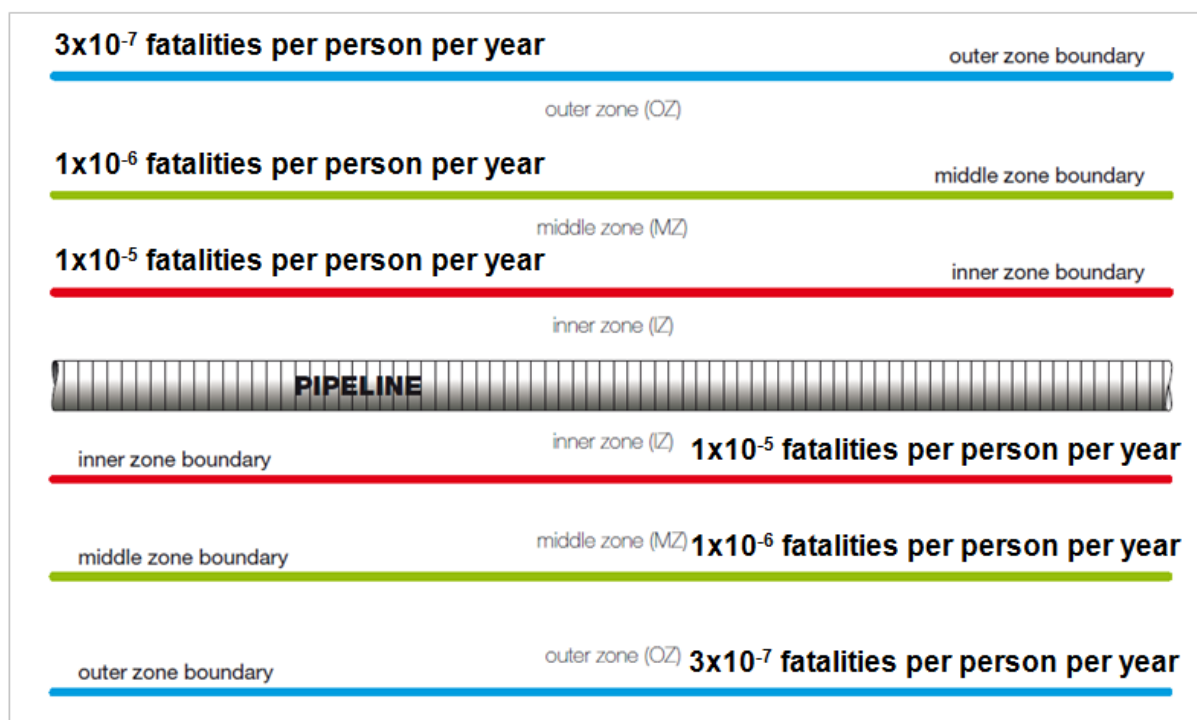


Figure 4-2: Town-planning zones for pipelines

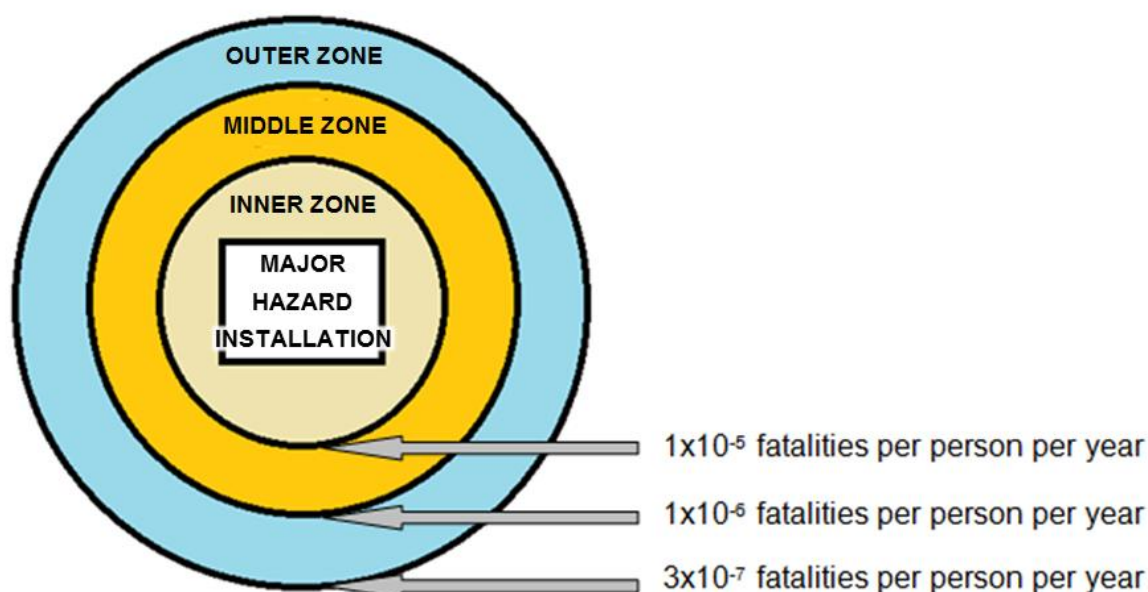


Figure 4-3: Town-planning zones

Once the zones are calculated, the HSE (UK) methodology then determines whether a development in a zone should be categorised as ‘advised against’ (AA) or as ‘don’t advise against’ (DAA), depending on the sensitivity of the development, as indicated in Table 4-13. There are no land-planning restrictions beyond the outer zone.

Table 4-13: Land-use decision matrix

Level of Sensitivity	Development in Inner Zone	Development in Middle Zone	Development in Outer Zone
1	DAA	DAA	DAA
2	AA	DAA	DAA
3	AA	AA	DAA
4	AA	AA	AA

The sensitivity levels are based on a clear rationale, in order to allow progressively more severe restrictions to be imposed as the sensitivity of the proposed development increases.

There are four sensitivity levels, with the sensitivity for housing defined below:

- Level 1: workers who have been advised of the hazards and trained accordingly;
- Level 2: based on the general public at home and involved in normal activities;
- Level 3: based on the vulnerable members of the public (e.g., children, those with mobility difficulties or those unable to recognise physical danger); and,
- Level 4: large examples of Level 3 and large examples of Level 2.

Refer to Appendix C for detailed PADHI (Planning Advice for Developments near Hazardous Installations) tables. These tables illustrate how the HSE land-use decision matrix, were generated by using the three zones and the four sensitivity levels, and applied a variety of development types.

4.5 Quantitative Risk Assessment (QRA) Scenarios

4.5.1 Methodology

A risk assessment done in accordance with the MHI regulations are required to be conducted according to SANS 1461 (2018). This standard is specific to the MHI risk assessment that is required to be done prior to construction and includes elements that is not usually available at the preparation, such as emergency plans and mitigation suggested during the EIA process.

SANS 1461 (2018) is based on RIVM (2009) for process plants. The latter standards describe the minimum scenarios to be included in the assessment, as well as the assumptions to be used. As full compliance of SANS 1461 (2018) cannot be achieved within the NEMA legislative framework, general compliance of the aforementioned standards would be applicable and briefly described in the sections below.

The QRA process is summarised with the following steps:

1. Identification of components that are flammable, toxic, reactive or corrosive and that have the potential to result in a major incident from fires, explosions or toxic releases;
2. Development of accidental loss of containment (LOC) scenarios for equipment containing hazardous components (including release rate, location and the orientation of the release);
3. For each incident developed in Step 2, determination of consequences (such as thermal radiation, domino effects, toxic-cloud formation and so forth); and,
4. For scenarios with off-site consequences (greater than 1% fatality off-site), calculation of maximum individual risk (MIR), taking into account all generic failure rates, initiating events (such as ignition), meteorological conditions and lethality.

Scenarios included in this QRA have impacts externally to the establishment. The 1% fatality from acute effects (thermal radiation, blast overpressure and toxic exposure) is determined as the endpoint (RIVM 2009). Thus, a scenario producing a fatality of less than 1% at the establishment boundary under worst-case meteorological conditions would be excluded from the QRA.

4.5.2 Scenario Selection

Guidelines for the selection of scenarios is given in RIVM (2009) and CPR 18E (Purple Book; 1999). A particular scenario may produce more than one major consequence. In such cases, consequences are evaluated separately and assigned failure frequencies in the risk analysis. Some of these phenomena are described in the subsections that follow.

4.5.2.1 Scenarios for Release of a Pressurised Liquefied Gas

The nature of the release of a liquefied gas from a pressurised vessel is dependent on the position of the hole.

A hole above the liquid level will result in a vapour release only, and the release rate would be related to the size of the hole and internal pressure of the tank. Over a period of time, bulk temperature reduces, with an associated decrease in the vapour release rate.

A hole below the liquid level will result in a release of a liquid stream. In the reduced pressure of the atmosphere, a portion of the liquid will vaporise at the normal boiling point. This phenomenon is called flashing and is shown in Figure 4-4. The pool, formed after flashing, then evaporates at a rate proportional to the pool area, surrounding temperature and wind velocity.

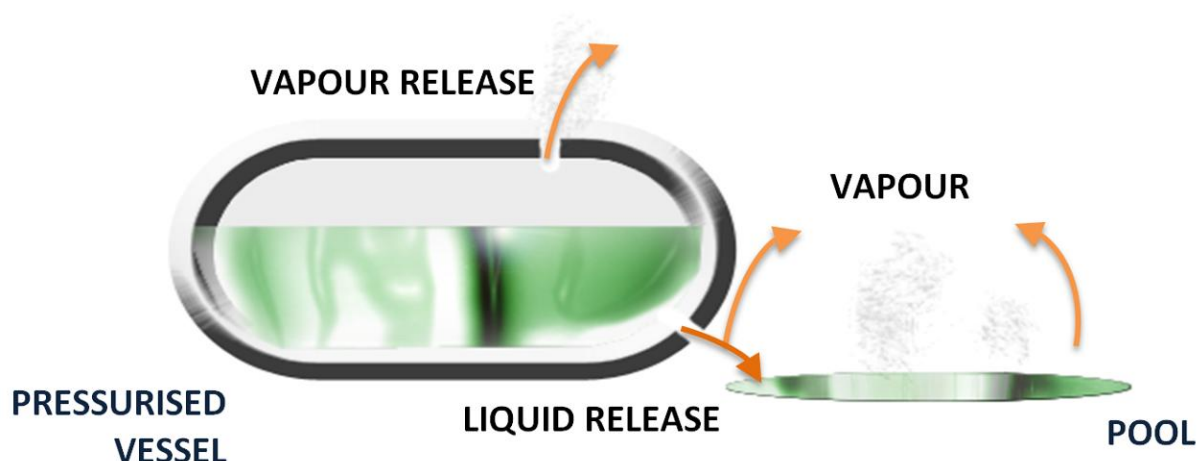


Figure 4-4: Airborne vapours from a loss of containment of liquefied gas stored in a pressurised vessel

4.5.2.2 *Instantaneous Release of a Pressured Liquefied Flammable Gas*

An instantaneous loss of containment of a liquefied flammable gas could result in the consequences, given in the event tree of Figure 4-5. Probability of the events occurring is dependent on a number of factors and is determined accordingly. All the scenarios shown in the figure are determined separately and reported in relevant subsections of the report.

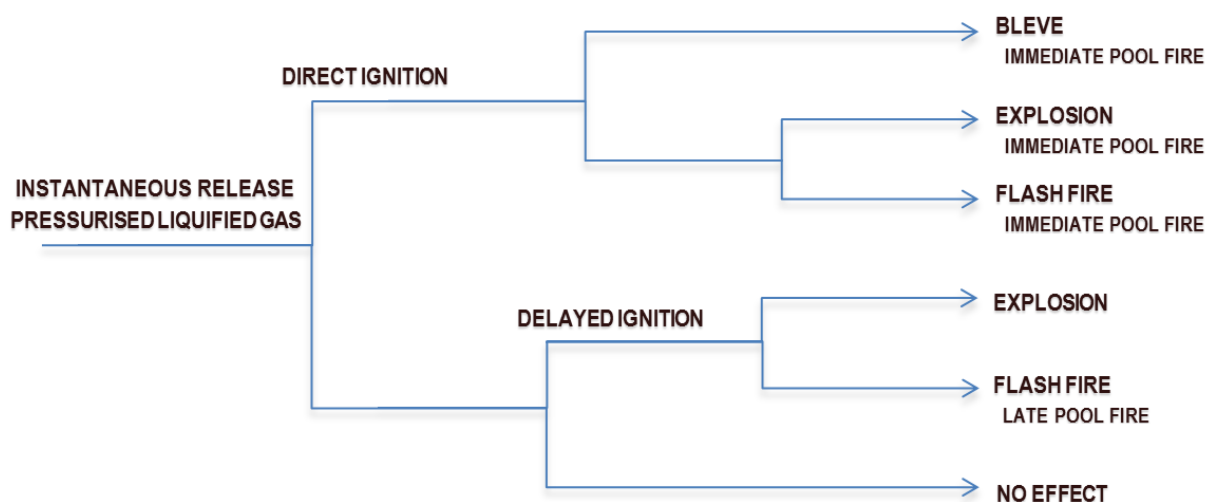


Figure 4-5: Event tree for an instantaneous release of a liquefied flammable gas

4.5.2.3 *Continuous Release of a Pressurised Liquefied Flammable Gas*

The continuous loss of containment of a liquefied flammable gas could result in the consequences, given in the event tree of Figure 4-6. Probability of the events occurring is dependent on a number of factors and is determined accordingly. All the scenarios shown in the figure are determined separately and reported in relevant subsections of the report.

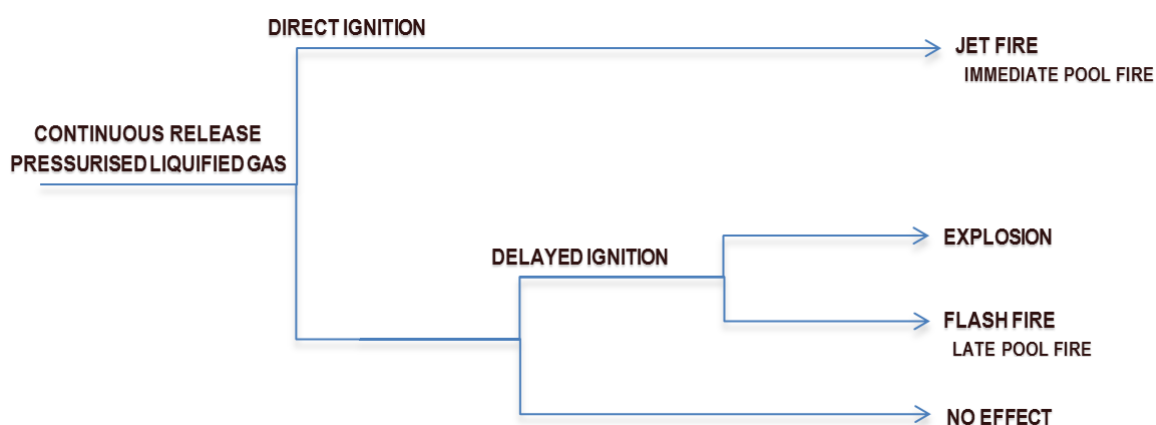


Figure 4-6: Event tree for a continuous release of a liquefied flammable gas

4.5.2.4 Continuous Release of a Flammable Gas

The continuous loss of containment of a flammable gas could result in the consequences, given in the event tree of Figure 4-7. Probability of the events occurring is dependent on a number of factors and is determined accordingly. All the scenarios shown in the figure are determined separately and reported in relevant sub-sections of the report.

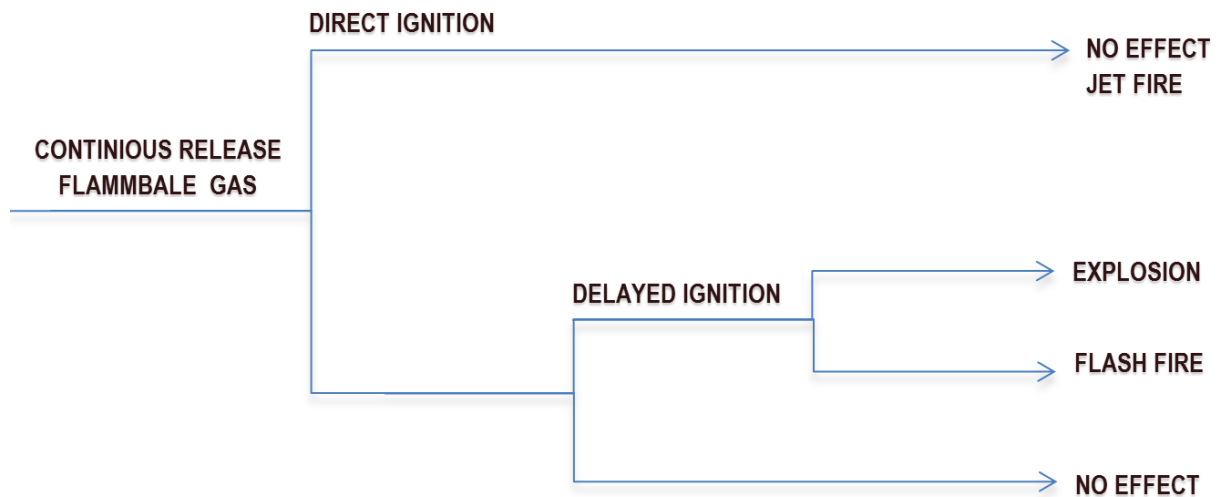


Figure 4-7: Event tree for a continuous release of a flammable gas

4.5.2.5 Continuous Release of a Flammable Liquid

The continuous loss of containment of a flammable liquid could result in the consequences, given in the event tree of Figure 4-8. Probability of the events occurring is dependent on a number of factors and is determined accordingly. All the scenarios shown in the figure are determined separately and reported in relevant subsections of the report.

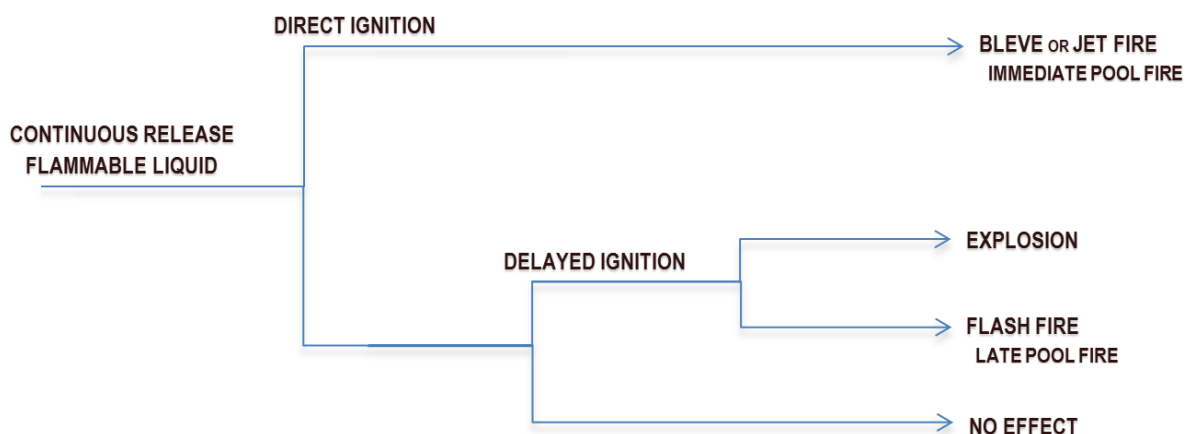


Figure 4-8: Event tree for a continuous release of a flammable liquid

5 RISK ASSESSMENT

A risk assessment was done for each processing unit by firstly selecting a scenario and then completing consequence and outflow modelling. Consequences with possible impacts beyond the site boundary were retained for risk analysis of the unit.

Finally, the risk of the entire facility is determined as a combination of the risk calculated for each unit.

5.1 Gas Wells and Gas Gathering Pipeline

5.1.1 Wells and Pipeline

In total, there are 43 well development locations that are located along known faults and close to either existing blowers or exploration wells drilled by D3 Energy. The initial development will focus on the wells located on the Virginia fault where there are 13 new well locations and 3 existing wells that will be utilised in the development.

Each well is expected to have a maximum pressure of 50 psig (3.5 bar) and a maximum flow rate 250 MMSCFD (295 m³/hr).

5.1.2 Consequence Modelling

5.1.2.1 Scenarios Modelled

The scenarios modelled for the wells and pipeline, are listed in Table 5-1.

Table 5-1: Scenarios modelled for the wells and pipeline

Equipment	Scenario	Remarks
Well	Catastrophic failure	
Pipeline	- Pipeline failure - Pipeline leak	- Pipeline diameter: 315 mm - Pipeline buried

5.1.2.2 Well Failure

A well failure would result in a vertical release of natural gas. In the event of a release without ignition, the flammable cloud is shown in Figure 5-1. The release will be a turbulent free jet, with a limited diameter at the reference level of 1 m above grade. To this end, the flammable region extends around the release jet, which has a small diameter and poses no significant potential for a vapour cloud explosion.

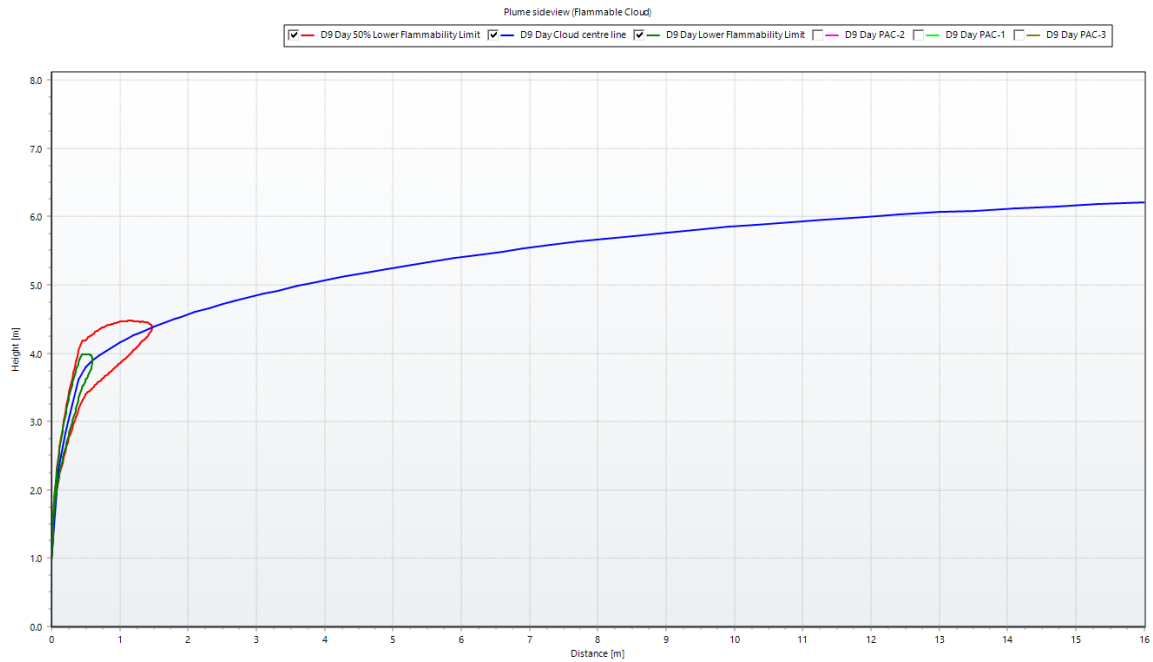


Figure 5-1: Maximum extent of the flammable cloud from a failure of an individual well (side-view)

In the event of an ignition, a jet fire could form in the vertical plane. A strong wind could tilt the flame producing thermal radiations, as shown in Figure 5-2.

The 4 kW/m^2 is capable of breaking glass and is the lower limit in emergency planning for escape routes. The 10 kW/m^2 is the value for the 1% fatality for unprotected people, with an exposure duration at 20 seconds. The 37.5 kW/m^2 represents the critical thermal radiation flux for damage to metal equipment.

The 1% fatality could extend 4m downwind from the release.

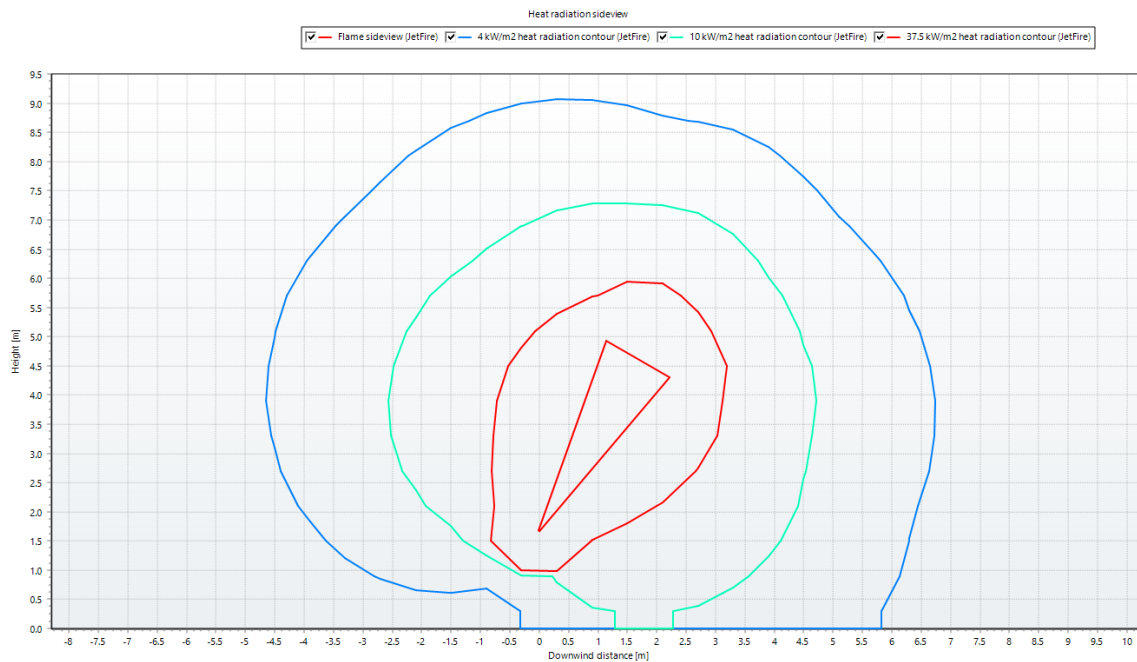


Figure 5-2: Side-view of the jet fire from a large release from a single well

5.1.2.3 Collection Pipeline

The maximum distance to the 1% fatality from a release of the natural gas pipeline, is shown in Figure 5-3. The maximum distance would occur with a high wind speed and could cause severe damage at the point of release, but it is not expected to impact residential areas.

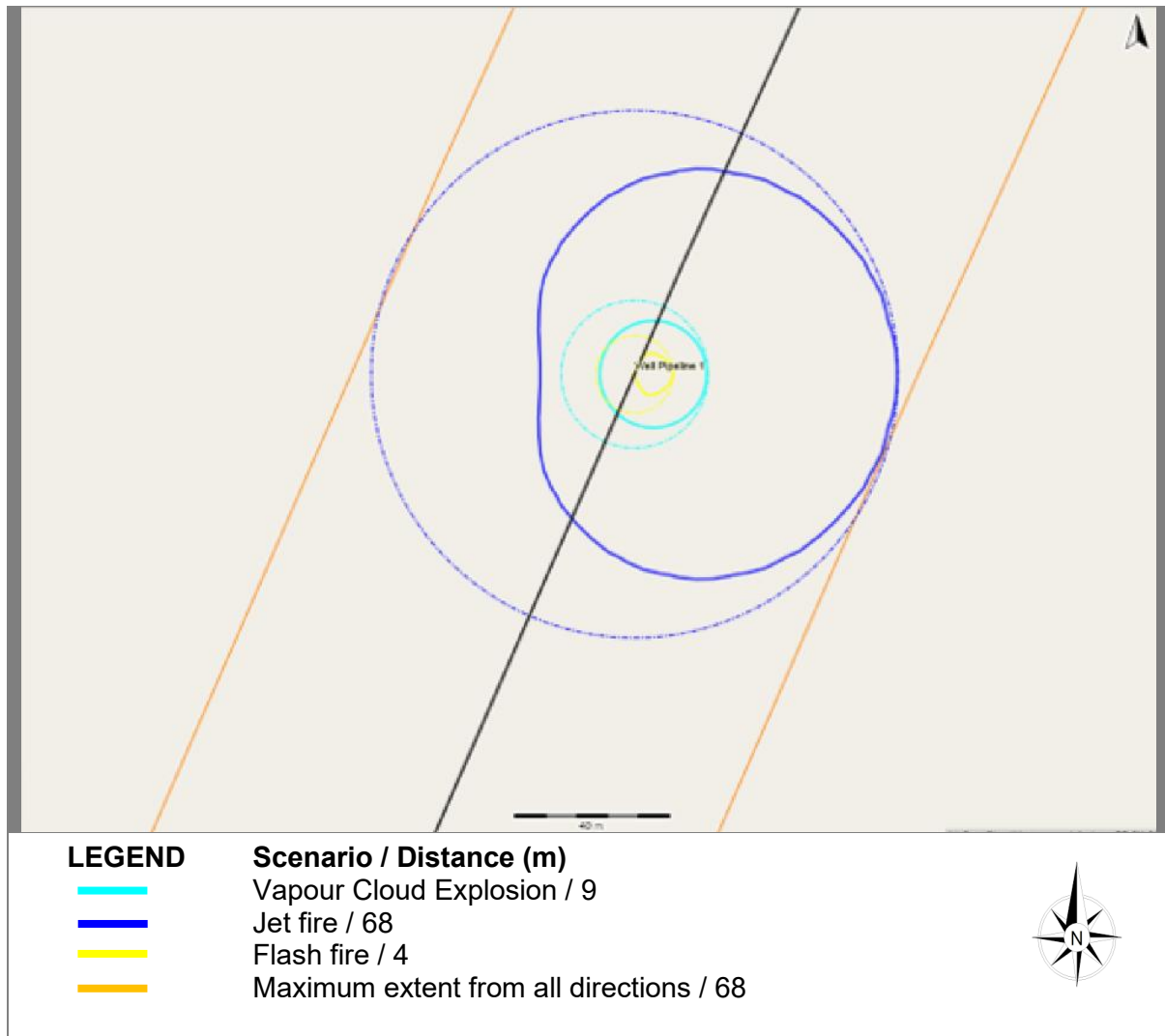


Figure 5-3: The maximum extent to the 1% fatality from the natural gas pipeline failure

5.2 Gas Processing Plant

5.2.1 The Purpose of the LNG Offloading, Storage and Vaporisation Process

The gas processing plant will receive gas from the well, extract the helium as a marketable product, and purify the remaining stream into saleable compressed natural gas (CNG) and liquefied natural gas (LNG).

5.2.2 Consequence Modelling

The scenarios modelled for the gas-to-power facility, are listed in Table 5-2. Some of these scenarios are discussed further in the sections below.

Table 5-2: Scenarios modelled for the gas-to-power facility

Equipment	Scenarios Modelled	Potential Consequences	Comments / Assumptions
Helium storage	- Catastrophic failure 10 Minute release 10 mm Hole	Toxic release (Asphyxiant)	- Volume: 110 m³ - Storage temperature: -269°C - Storage pressure: 0.32 bar(g)
Helium tanker	- Tanker failure - Hose failure - Hose leak	Toxic release (Asphyxiant)	- ISO Tank container: 41 m³ 1 x ISO Tank container / week
LNG tanker	- Tanker failure - Hose failure - Hose leak	- Pool fires - Flash fires - VCE	- Road tankers: 45 m³ - 5 Road tankers per week - Pressure: 300 kpa(g) - Temperature: -162°C
CNG storage	- Catastrophic failure 10 Minute release 10 mm Hole	- Jet fires - Flash fires - VCE	- Capacity: 25 m³ - Pressure: 260 bar(g) - Temperature: 35°C
CNG tanker	- Tanker failure - Hose failure - Hose leak	- Jet fires - Flash fires - VCE	- Road tankers: 8 Road tankers per day - Pressure: 260 bar(g) - Temperature: 35°C
CNG compressor	Failure	- Jet fires - Flash fires - VCE	- Flow: 165 m³/day - Pressure: 260 bar(g) - Temperature: 35°C

5.2.2.1 Helium

Helium is not a toxic gas, but may displace oxygen resulting in asphyxiation and is analysed in a similar manner to toxic gas.

The 1% fatality represents the endpoint for risk assessment calculations, with various scenarios shown in Figure 5-4. Fatalities from a large release of helium will be limited to the site.

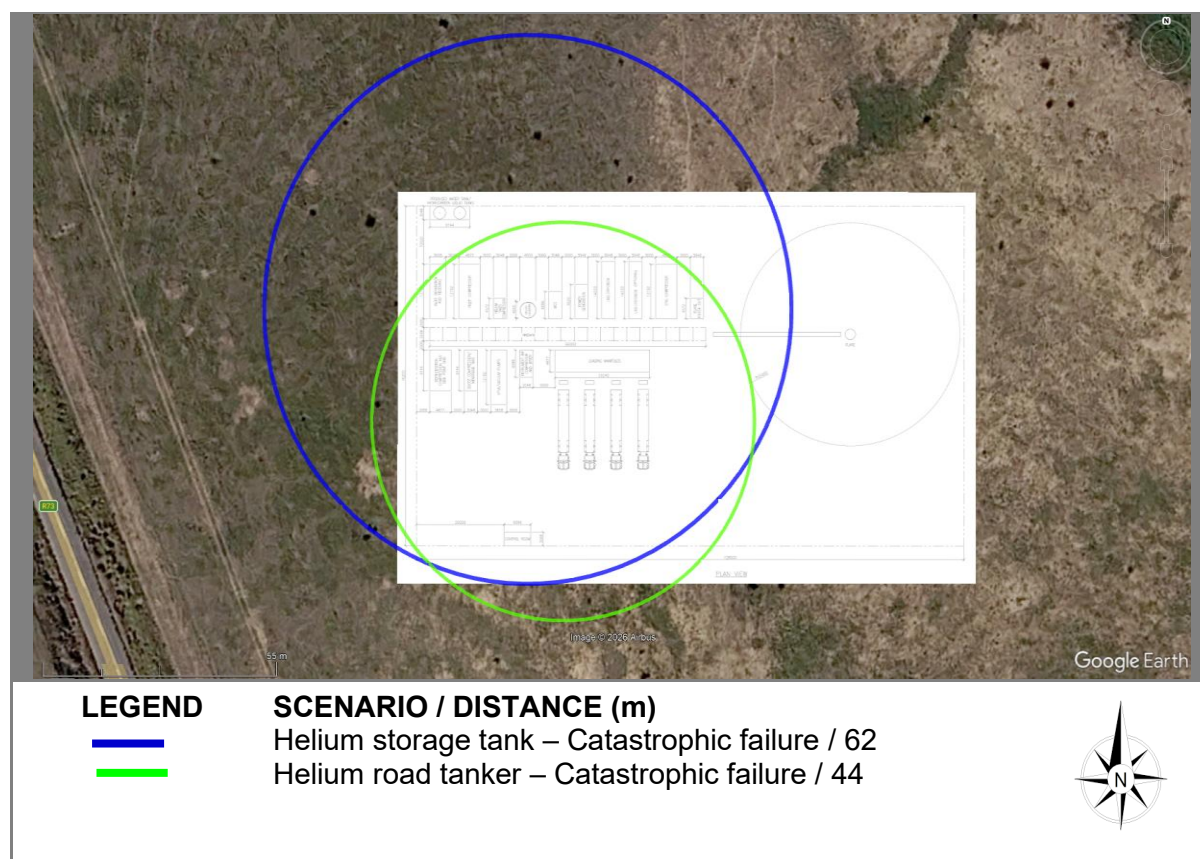


Figure 5-4: The extent of an expected 1% fatality in the open following large releases of helium

5.2.2.2 Ammonia

Ammonia used in the refrigeration system is listed by the EPA as being extremely toxic. It is stored in vessels within the refrigeration plant and is used as a refrigerant.

PAC-3 is the maximum air concentration below, which it is believed that nearly all individuals could be exposed without experiencing or developing life-threatening health effects. The PAC-2 concentration is the maximum air concentration below, which it is believed nearly all individuals could be exposed without experiencing or developing irreversible or serious health effects or symptoms that could impair an individual's ability to take protective action. The PAC-2 value is used for emergency planning to indicate the furthest downwind distance for evacuation of nearby populations in the event of a release.

Figure 5-5 illustrates the PAC-2 and PAC-3 endpoint distances and the 1% fatality endpoint distance for the worst-case release scenario in worst-case meteorological conditions. This was found to be the fixed duration release of the -10°C surge tank at a low wind speed.

The thicker lines indicate a westerly wind, while the thinner lines indicate all wind directions.

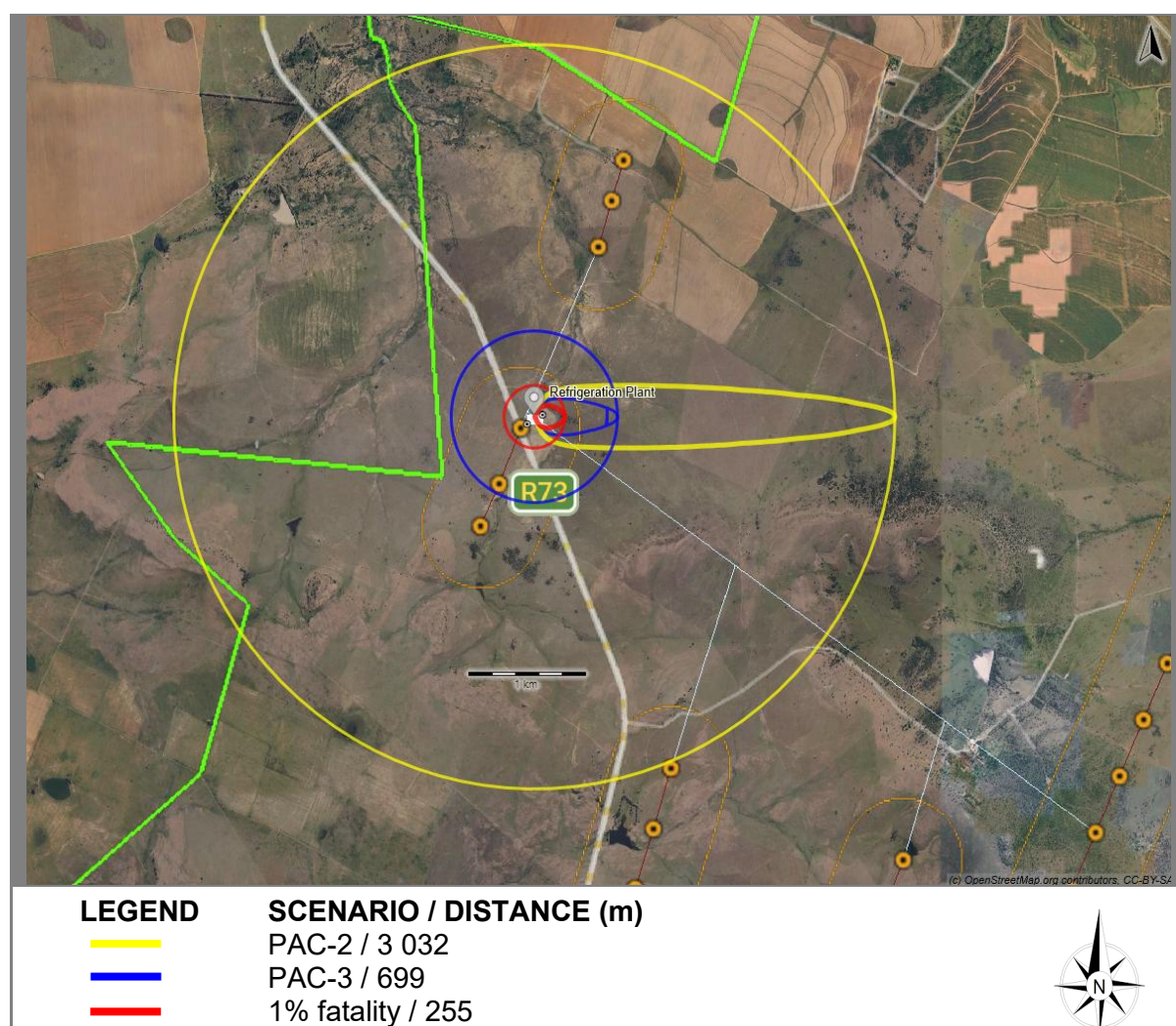


Figure 5-5: The maximum extent of the impact of air concentrations of ammonia following a large release of ammonia, using the PAC-2 and PAC-3 value and the 1% fatality at the reference level of 1 m above the ground

The impacts from a large ammonia release could extend up to 3 km downwind to the PAC-2 endpoint, representing the evacuation endpoint. No fatalities would be expected in nearby residential areas. The PAC-2 distance is substantial and is retained for emergency-planning purposes; the identified residential receptors are beyond this modelled endpoint. PAC-2 denotes the distance at which serious or irreversible health effects may occur, rather than a fatality contour.

5.2.2.3 LNG Loading Gantry

The LNG will be loaded into road tankers at a frequency of 5 tankers per week.

The maximum extent to the 1% fatality will occur from a catastrophic failure of a 60 m³ road tanker at low wind speeds, as shown in Figure 5-6. The thin lines show the maximum extent of the potential effects from a westerly wind direction, while the thicker coloured lines indicate the maximum distance from all directions.

In this case, the flash fire dominates the impacts and determines the maximum extent to the 1% fatality. The 1% fatality for the VCE would result in damage to equipment within the gas processing plant, but would not extend beyond the site boundary and would not impact residential areas.

The impacts from a vapour cloud explosion could result in damage to the LNG storage vessels and piping, that could result in a knock-on effect. However, good engineering of the LNG storage vessels can minimise such events.

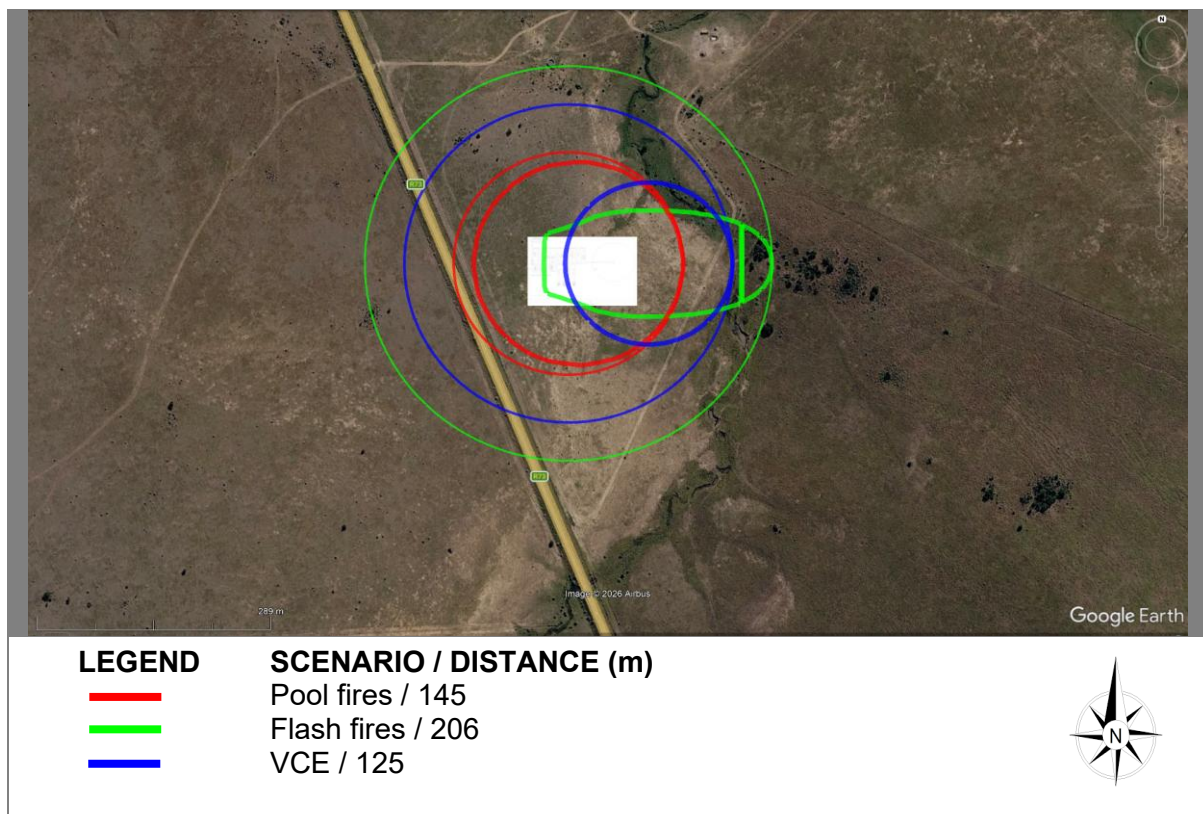


Figure 5-6: The maximum extent to the 1% fatality from a catastrophic failure of a 60 m³ road tanker

5.2.2.4 CNG Storage

The CNG will be stored in a 25 m³ storage tank at 260 bar(g).

The maximum extent to the 1% fatality will occur from a release of the instantaneously failure of the 25 m³ CNG storage tank, as shown in Figure 5-7. The thick lines show the maximum extent of the potential effects from a westerly wind direction, while the thin lines indicate the maximum extent from all wind directions.

In this case, the flash fire dominates the impacts and determines the maximum extent to the 1% fatality. The 1% fatality for the VCE would result in damage to the gas processing plant and may extend beyond the R73 road.

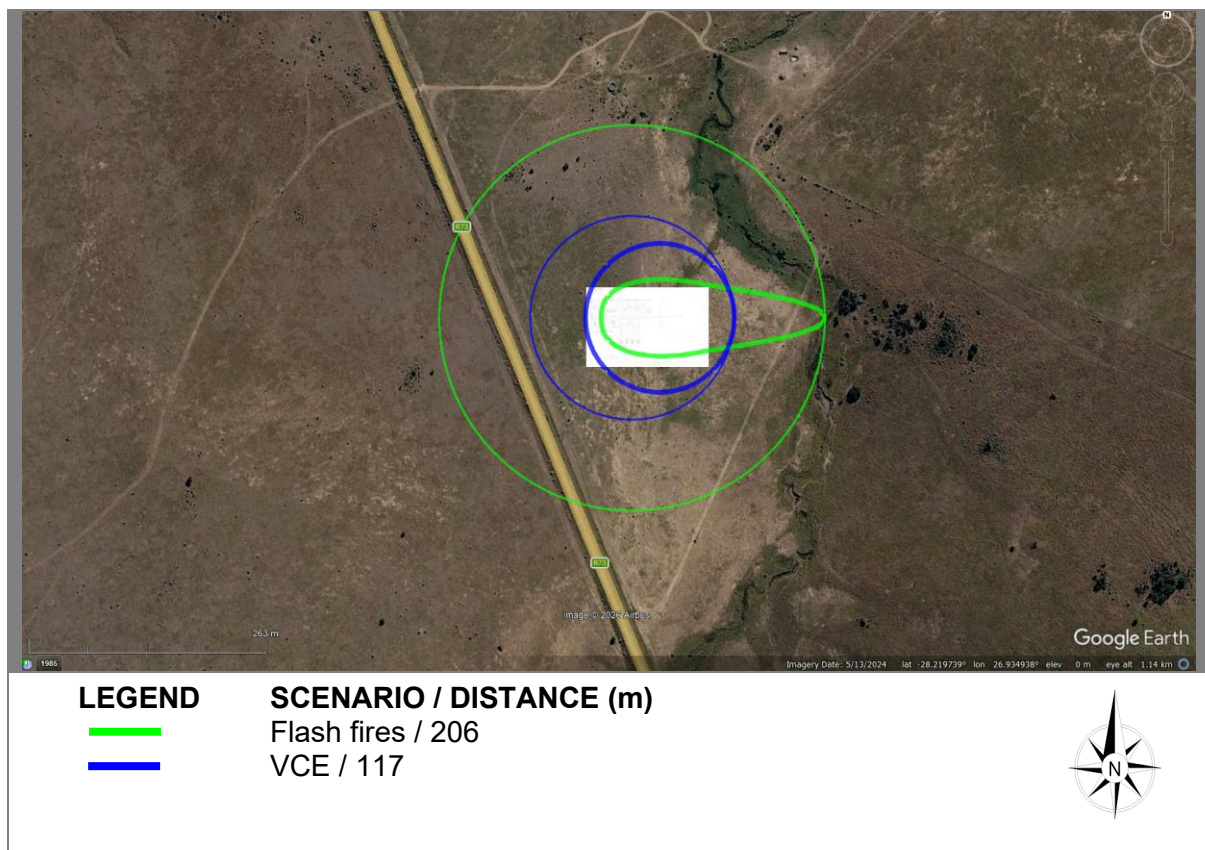


Figure 5-7: The maximum extent to the 1% fatality from a catastrophic failure of a 25 m³ CNG storage tank

5.2.2.5 CNG Loading Gantry

CNG will be loaded into trucks with a capacity of 22 m³ and a pressure at 260 bar(g).

The maximum extent to the 1% fatality will occur from a release of the instantaneously failure of the 22 m³ CNG road tanker, as shown in Figure 5-8. The thick lines show the maximum extent of the potential effects from a westerly wind direction, while the thin lines indicate the maximum extent from all wind directions.

In this case, the flash fire dominates the impacts and determines the maximum extent to the 1% fatality. The 1% fatality for the VCE would result in damage to the gas processing plant and may extend beyond the R73 road.

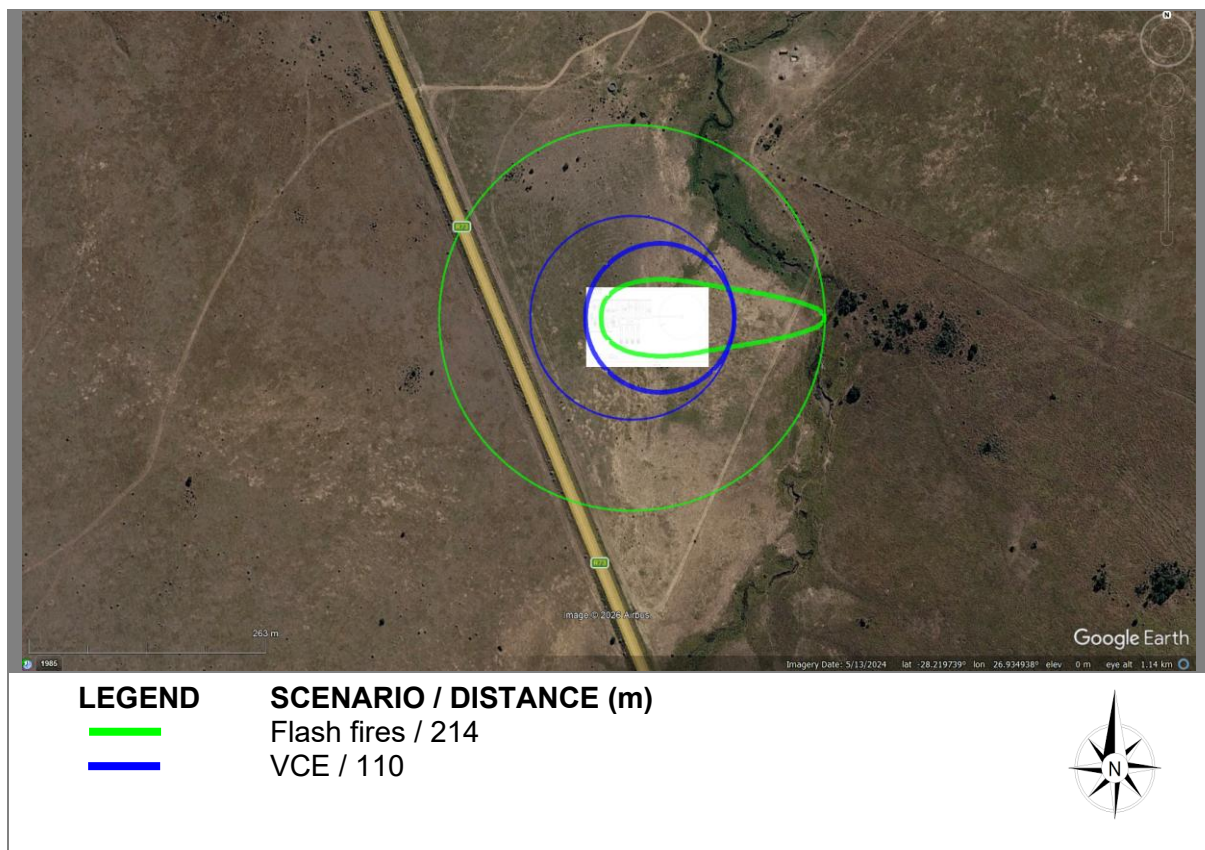


Figure 5-8: The maximum extent to the 1% fatality from a catastrophic failure of a 22 m³ CNG road tanker

5.3 Flare

5.3.1 The Purpose of the Processing Unit

The purpose of the flare is to safely remove the dangers of flammable materials by combusting the materials at an elevated height.

5.3.2 Hazardous Components

In this study, the flammable material removed by the flare was modelled as methane.

5.3.2.1 Acceptable Radiation Levels

Guideline levels for thermal radiation from continuous and emergency flaring, are given in the API 521 (2007) standard and are listed below in Table 5-3. The maximum thermal radiation should be evaluated against these guidelines. It should be noted that the maximum radiation would depend on the wind speed, flare design and exiting velocity.

Table 5-3: Recommended design thermal radiation for personnel (API 521-2007)

Permissible Design Level (kW/m ² ; Btu/h·ft ²)	Conditions
9.46; 3000	Maximum radiant heat intensity at any location where urgent emergency action by personnel is required. When personnel enter or work in an area with the potential for radiant heat intensity greater than 6.31 kW/m ² (2000 Btu/h·ft ²), then radiation shielding or special protective apparel (e.g. a fire approach suit) should be considered. SAFETY PRECAUTION: It is important to recognise that personnel with appropriate clothing¹ cannot tolerate thermal radiation at 6.31 kW/m² (2000 Btu/h·ft²) for more than a few seconds.
6.31; 2000	Maximum radiant heat intensity in areas where emergency actions lasting up to 30 sec can be required by personnel without shielding, but with appropriate clothing ¹ .
4.73; 1500	Maximum radiant heat intensity in areas where emergency actions lasting 2 min to 3 min can be required by personnel without shielding, but with appropriate clothing ¹ .
1.58; 500	Maximum radiant heat intensity at any location where personnel with appropriate clothing ¹ can be continuously exposed.

¹ Appropriate clothing consists of a hard hat, long-sleeved shirts with cuffs buttoned, work gloves, long-legged pants and work shoes. Appropriate clothing minimises direct skin exposure to thermal radiation.

5.3.2.2 Process Flare

In the pilot-flame mode, the flare remains small, consuming minimal fuel to sustain the flame.

The thermal radiation of 1.58 kW/m^2 (the radiation that permits continual exposure with appropriate clothing) that occurs during the flare operation, is shown in Figure 5-9. This level is not expected to reach ground level.

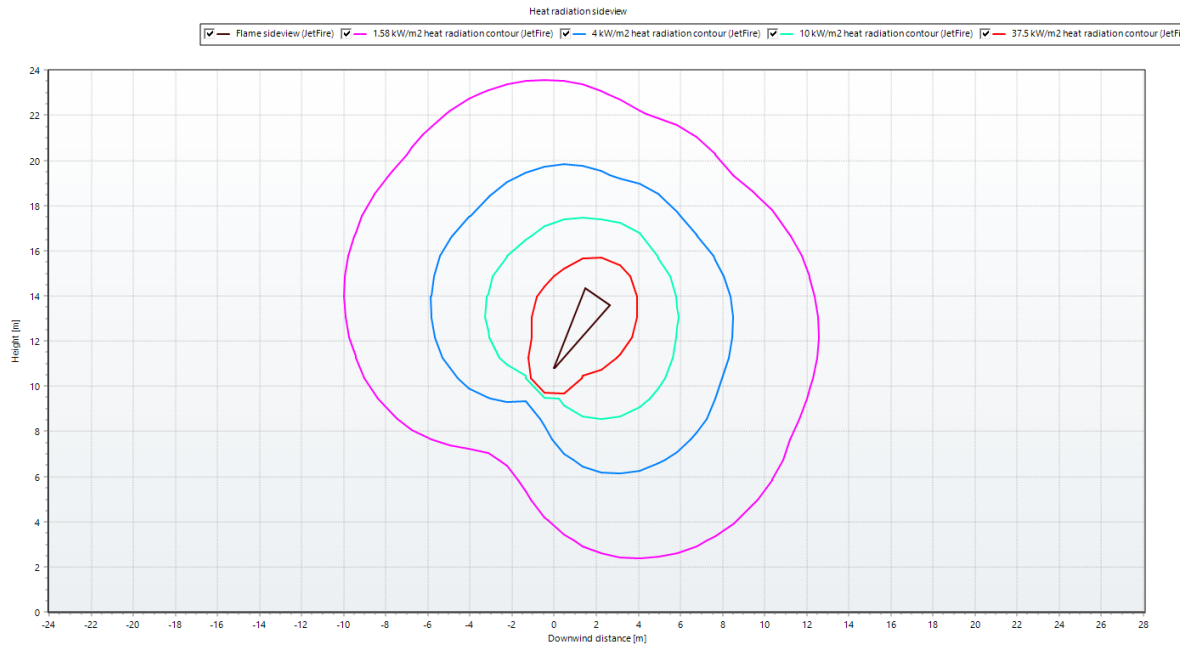


Figure 5-9: Thermal radiation that occurs during the flare operation

In the event of a flame-out, a potential flammable cloud could form with potential flash fires, as shown in Figure 5-10. Under the worst meteorological conditions of a strong wind, the flammable cloud would not reach the representative height of the receiver at 1 m above the ground.

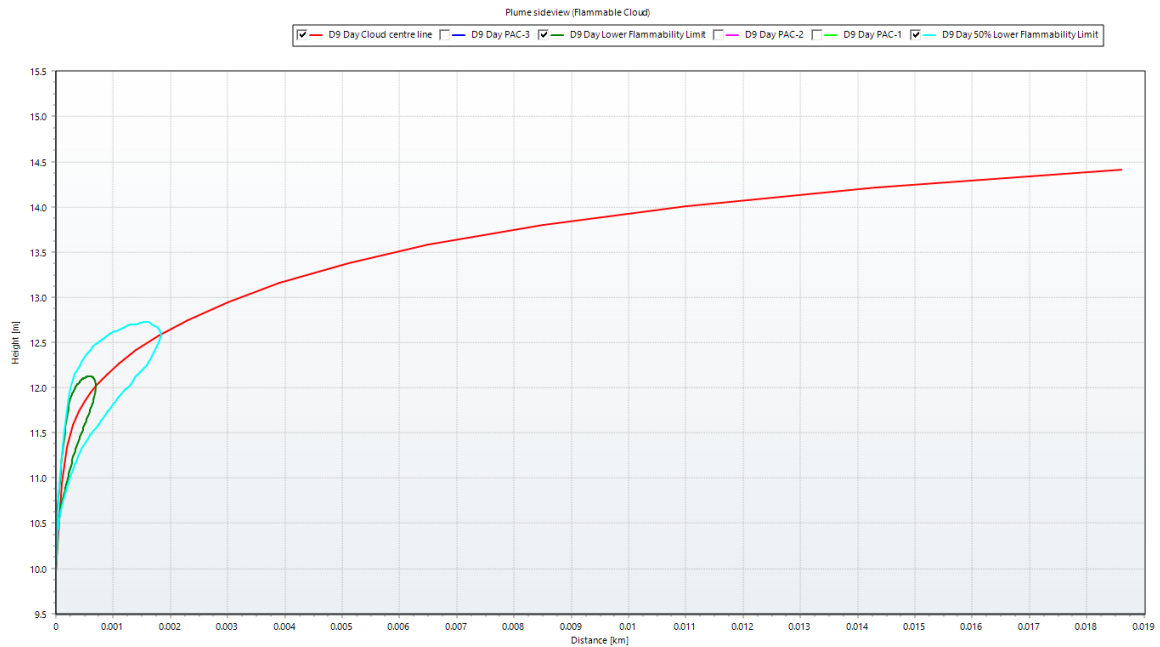


Figure 5-10: Maximum extent of a flammable cloud that occurs during a flame-out flare operation

5.4 Combined Site Individual Risk

Considering the extent of the consequences of the releases contemplated in the preceding subsections of Section 5 and others, as well as the frequency of occurrence of each release, the combined site risk is the summation of all the individual risks and is shown in Figure 5-11, with the enlarged map shown in Figure 5-13.

Individual risk, as introduced in Section 8.7, describes the chance of fatality of an individual situated at a particular location, due to operations onsite. The maximum individual risk assumes that an individual is situated at a particular location 24 hours per day for 365 days per year. This tends to be an overstatement of risk, but one generally accepted as sufficiently conservative.

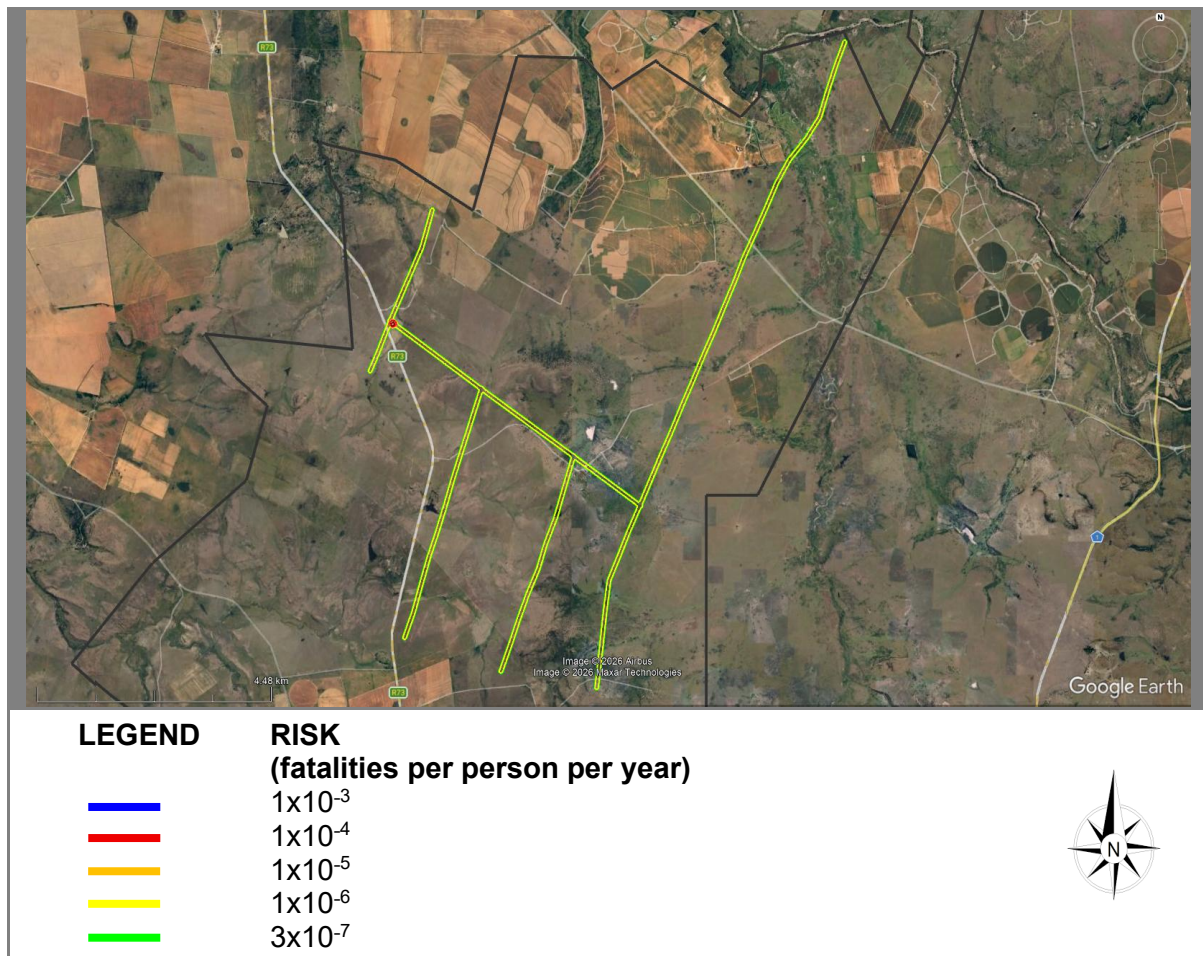


Figure 5-11: Individual risk contours – Combined risk

The alternative pipeline routing, is shown in Figure 5-12. Road crossings along the gas gathering pipeline routes require special attention during detailed design, construction and operation, and additional mitigation may be required at these locations. Each crossing should be subject to a site-specific assessment that considers traffic loading, burial depth, pipe protection, third-party interference and emergency access. Appropriate measures may include increased cover or protective sleeves, clearly marked crossing points, controlled excavation procedures, suitable isolation and leak-detection arrangements, and coordination with the relevant road authority. Crossings of higher-traffic roads should be prioritised for enhanced inspection and integrity monitoring because a loss of containment at these locations could expose road users and complicate emergency response.

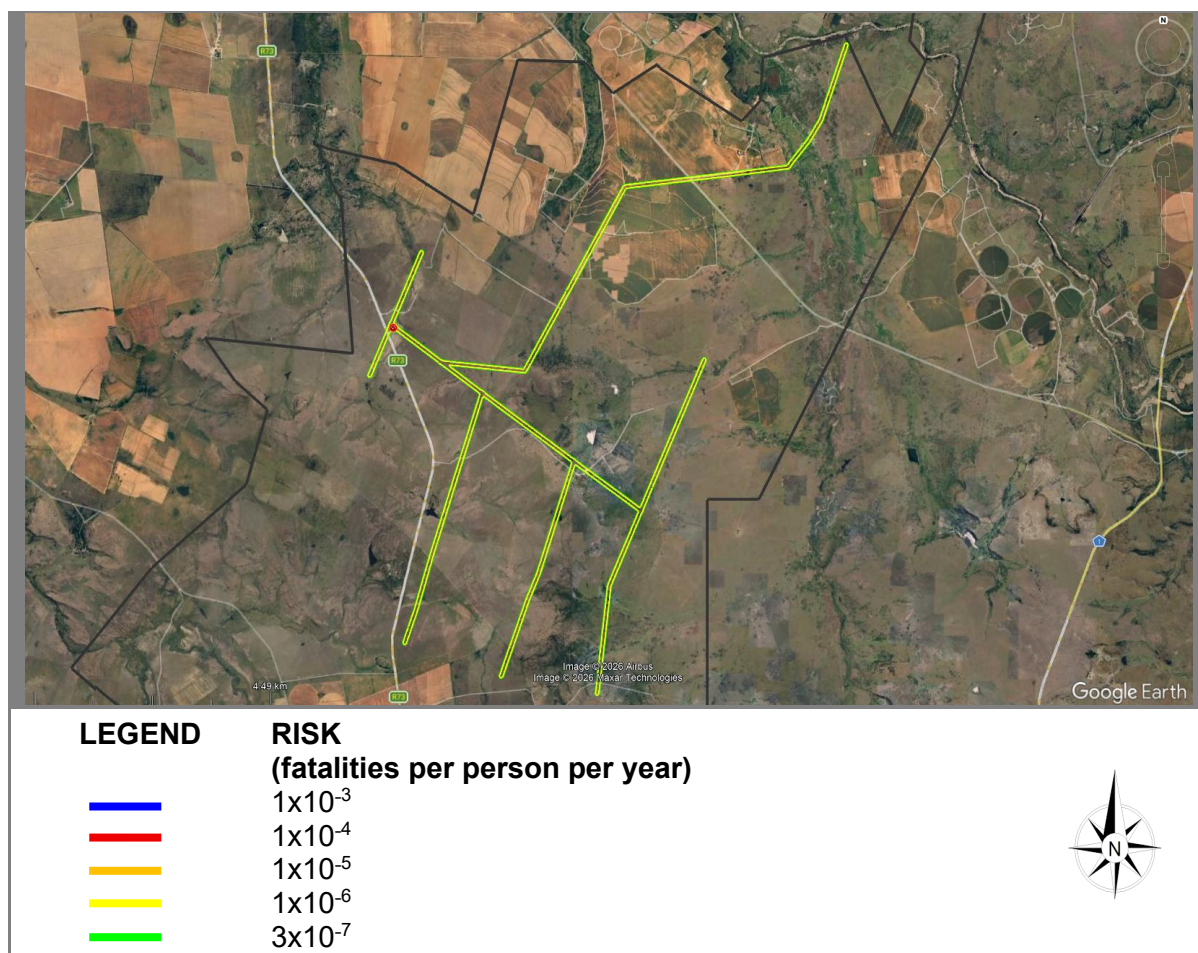


Figure 5-12: Individual risk contours – Combined risk for the alternative pipeline routing

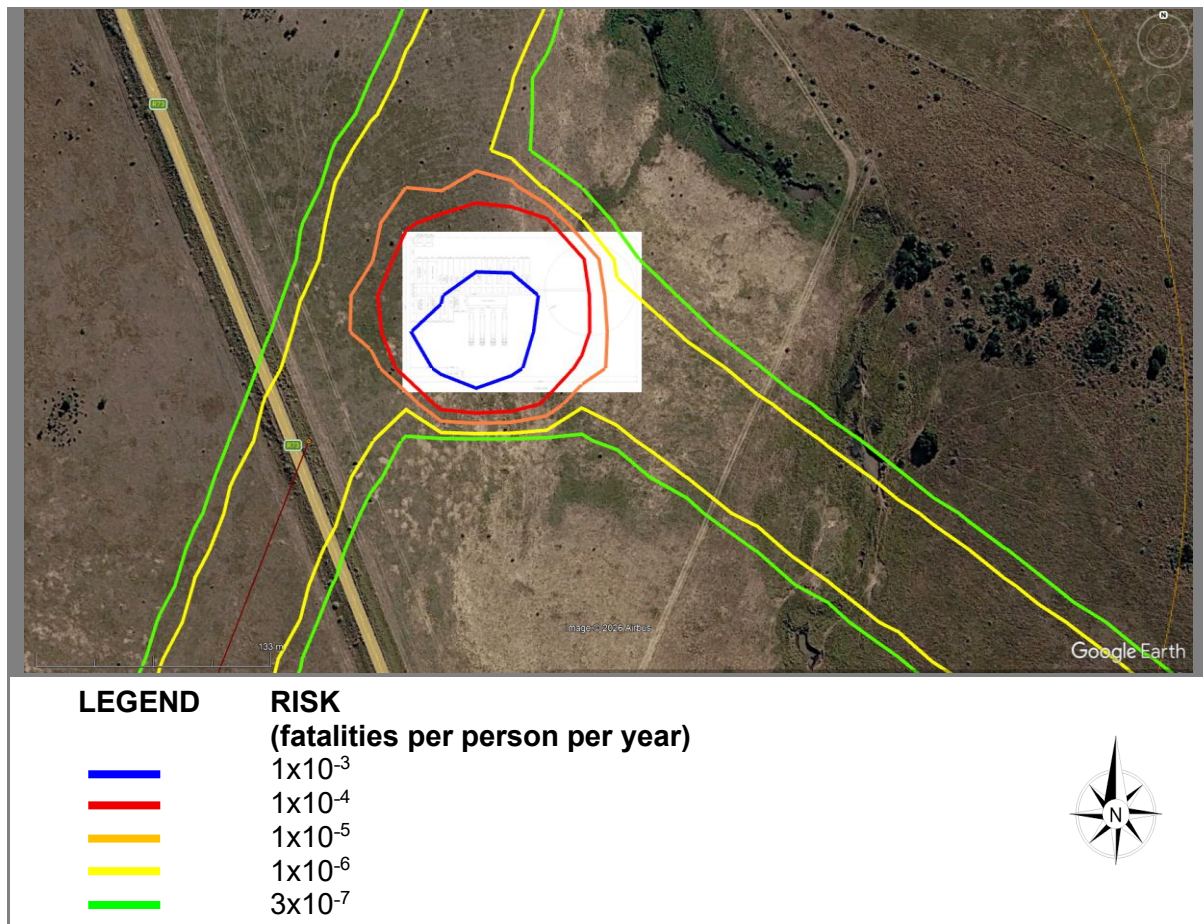


Figure 5-13: Individual risk contours – Combined risk enlarged

The individual risk contours illustrated in Figure 5-13 extend as follows:

- The 3×10^{-7} fatalities per person per year contour does not extend into residential areas. This contour represents the threshold for 'trivial' risk and represent acceptability to vulnerable people outside of the isopleth. Risks below this threshold is considered trivial.
- The risks between the 3×10^{-7} and 1×10^{-6} fatalities per person per year is considered 'broadly acceptable' to the general public, but 'tolerable if proven to be ALARP' for vulnerable populations such as hospitals, retirement homes, nursery schools, prisons, large gatherings in the open, and so forth.
- The 1×10^{-4} fatalities per person per year is considered excessive to the general public and does not extend into residential areas.
- The 1×10^{-3} fatalities per person per year contour, is considered excessive to workers and is located within the processing plant and would have to be mitigated prior to construction. This is related to the assumed LNG storage and particularly the overfilling protection.

Acceptability criteria for an individual risk are detailed in Section 8.7. No new land planning should be approved without the consultation of the PADHI land-planning tables described in Appendix C.

5.5 Risk Ranking

This risk assessment considered numerous scenarios determining both the consequences and the probability of a release. Some scenarios have more serious consequences than others. However, the scenarios of particular interest are those with high-risk frequencies extending beyond the boundary of the site.

Table 5-4 gives the off-site risk rankings at analysis point 1 and Table 5-5 gives the off-site risk rankings at analysis point 2 of the largest contributors to off-site risks for certain analysis points. The ranking can be used to effectively mitigate risks by prioritisation and by the setting of budgets.

Table 5-4: Off-site risk rankings at analysis point 1

Scenario	Risk Contribution [%]
LNG Road tanker- Hose failure (CNG Road Tanker)	96.5
LNG Trailer - Hose failure (LNG Trailer)	2.41
Gas LOC scenario (Long Pipeline) - Leak (Well Pipeline 5)	0.459
Surge vessel - 10 mm Hole (Refrigeration Plant)	0.201
Ammonia Receiver - 10 mm Hole (Refrigeration Plant)	0.145
LNG Gas (Long Pipeline) - Failure (Well Pipeline 5)	0.114
CNG - Catastrophic failure (BLEVE) (CNG Tank)	0.0299
Helium Storage - Catastrophic failure (Helium Storage Tank)	0.0293
Surge Vessel - Catastrophic failure (Refrigeration Plant)	0.0247
CNG Tank - Catastrophic failure (CNG Tank)	0.0224

Table 5-5: Off-site risk rankings at analysis point 2

Scenario	Risk Contribution [%]
LNG Road Tanker- Hose failure (CNG Road Tanker)	99.9
Ammonia Receiver - 10 mm Hole (Refrigeration Plant)	0.0168
Surge Vessel - 10 mm Hole (Refrigeration Plant)	0.0151
CNG - Catastrophic failure (BLEVE) (CNG Tank)	0.00943
Surge Vessel - Fixed duration (Refrigeration Plant)	0.00797
CNG Tank - Catastrophic failure (CNG Tank)	0.00707
ISO Tank Container - Catastrophic failure (Helium ISO Tank Container)	0.0027
Gas LOC Scenario (Long Pipeline) - Leak (Well Pipeline 5)	0.00244
LNG Trailer - Failure (LNG Trailer)	0.00212
LNG Road Tanker - Catastrophic failure (CNG Road Tanker)	0.00141

The analysis points, are shown in Figure 5-14.

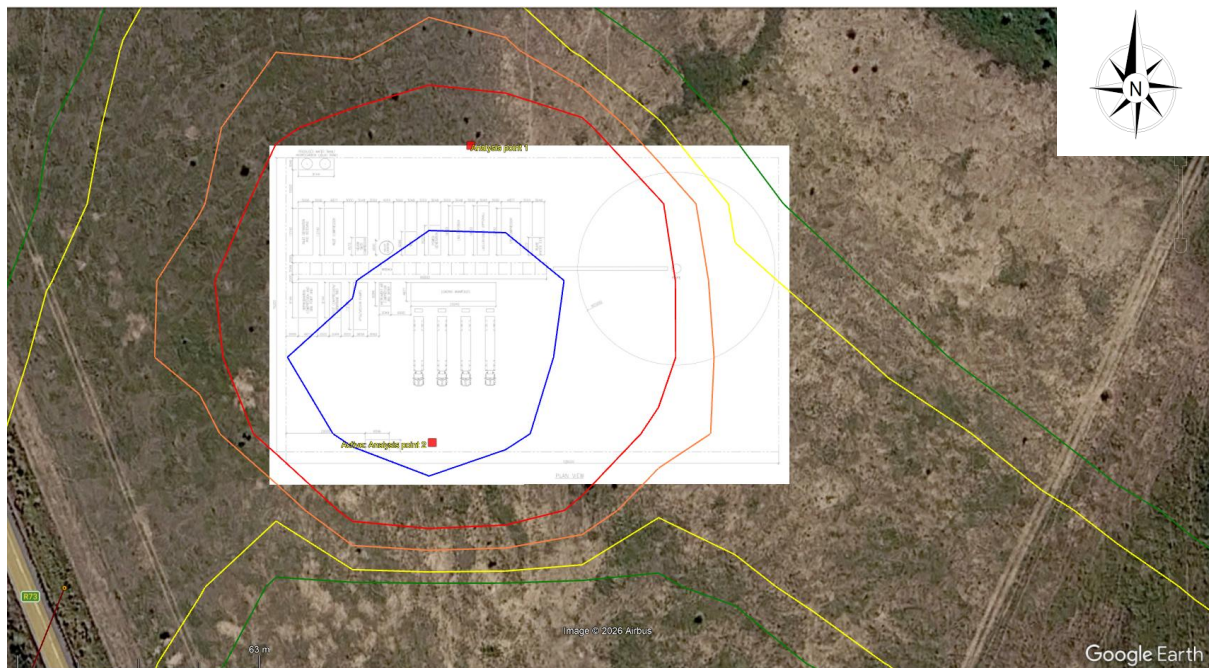


Figure 5-14: Analysis points

The largest risk is the failure of the LNG road tanker hose failure, which would make the risks to the workers excessive. It is advised that mitigation should be considered to reduce the risks to acceptable levels.

6 RISK REDUCTION

From the simulations performed, the areas of highest risk have been identified as the release of LNG at various process units.

Mitigation that may be considered to reduce risks to acceptable levels is listed in following subsections.

6.1 Mitigation

It should be noted that the suggested mitigation is for consideration only. RISCUM does not imply that the suggested mitigation should be implemented or that any suggested mitigation is the only measure to reduce risks. Furthermore, the implementation of some or all of the suggested mitigation would not guarantee full compliance with the Major Hazard Installation regulations.

The implementation of any mitigation should always be done in accordance with recognised engineering practices, by using applicable codes and standards.

6.1.1 Hazardous Materials Inventory

The first stage of mitigation is to either eliminate materials or reduce the inventory. For example, the inventories of ammonia could be reduced. This would need to be optimised with the frequencies of deliveries.

6.1.2 Substitution of Hazardous Materials

In some cases, the hazardous materials can be substituted. For example, anhydrous ammonia can be substituted with a less harmful ammonium hydroxide.

6.1.3 Process Hazard Analysis (PHA)

Hazardous areas should be reviewed by using a detailed Process Hazard Analysis (PHA)¹, such as a HAZOP study. This should be completed to identify the potential hazards, and suggest further mitigation for safer operations. Due to the seriousness of the hazardous material stored, transported and produced on site, it is suggested that a detailed PHA / HAZOP study should be completed by an independent chairman, who is registered with the Engineering Council of South Africa. Furthermore, any instruments used should incorporate the findings of a SIL assessment defined in IEC 61511.

¹ A Process Hazard Analysis is a highly regulated activity, which identifies potential hazards and recommends mitigation strategies.

6.1.4 Codes and Standards

Applicable international best practice fluorine production and guidelines or equivalent international recognised codes of good design and practice of fluorine installations, must be incorporated in the designs. This implies that best practices would be applied to the design and operation of the proposed plants.

6.1.5 Safety Instrumented Systems

IEC 61508/61511 (Safety Instrumented Systems) are codes specifically related to the instrumentation requirements for adequate protection from hazards in chemical plants and is applicable for the life cycle of the plant. These codes are aimed at reducing risks to surrounding populations to acceptable levels.

The significance of these codes is that the designs would be evaluated against the criteria of the code, and instrumentation with specific failure rates would be specified, as well as the minimum periods of checking. Thus, the selection of instrumentation is not based on the price alone. Further to this, instrumentation cannot be reduced or changed without reviewing the code. The specification of this code implies that designs presented at EIA and MHI evaluations cannot be altered at construction for the sole function of reducing costs. Moreover, the code ensures that the plant would continue to maintain the safety functions for the *life cycle* of the plant, retaining a safe working environment for both the workers and the public.

The European standards body, CENELEC, has adopted the standard as EN 61511. This means that in each of the member states of the European Union, the standard is published as a national standard. For example, in Great Britain, it is published by the national standards body, BSI, as BS EN 61511. The content of these national publications is identical to that of IEC 61511. Note, however, that EN 61511 is not harmonized under any directive of the European Commission.

In the United States ANSI/ISA 84.00.01-2004 was issued in September 2004. It primarily mirrors IEC 61511 in content with the exception that it contains a grandfathering clause.

Compliance with IEC 61508 and EN 61511 (or ANSI/ISA 84.00.01-2004) would be a requirement in many countries around the world to achieve an acceptable risk to the workers and the public.

Demonstrating compliance with the IEC61508/11 can be achieved only once full-detail designs have been completed, and is thus premature at this stage in the project.

It should be noted that RISCOM would suggest a FULL compliance of the IEC61508/11, with a full audit by an independent body (other than RISCOM), in order to support the project.

7 IMPACT ASSESSMENT

7.1 Procedure

The impact significance rating methodology, as presented herein and utilised for all EIMS Impact Assessment Projects, is guided by the requirements of the NEMA EIA Regulations 2014 (as amended). The approach may be altered or substituted on a case-by-case basis if the specific aspect being assessed requires such - such instances require prior EIMS Project Manager approval. The broad approach to the significance rating methodology is to determine the significance (S) of an environmental risk or impact by considering the consequence (C) of each impact (comprising Nature, Extent, Duration, Magnitude, and Reversibility) and relating this to the probability / likelihood (P) of the impact occurring. The S is determined for the pre- and post-mitigation scenario. In addition, other factors, including cumulative impacts and the potential for irreplaceable loss of resources, are used to determine a prioritisation factor (PF) which is applied to the S to determine the overall final significance rating (FS). The impact assessment will be applied to all identified alternatives.

7.1.1 Determination of Significance

The final significance (FS) of an impact or risk is determined by applying a prioritisation factor (PF) to the post-mitigation environmental significance. The significance is dependent on the consequence (C) of the particular impact and the probability (P) of the impact occurring. Consequence is determined through the consideration of the Nature (N), Extent (E), Duration (D), Magnitude (M), and Reversibility (R) applicable to the specific impact.

For the purpose of this methodology the consequence of the impact is represented by:

$$C = \frac{(E + D + M + R) * N}{4}$$

Each individual aspect in the determination of the consequence is represented by a rating scale as defined in Table 7-1.

Table 7-1: Criteria for Determining Impact Consequence

Aspect	Score	Definition
Nature	- 1	Likely to result in a negative / detrimental impact.
	+1	Likely to result in a positive / beneficial impact.
Extent	1	Activity (i.e. Highly localised, limited to the area applicable to the specific activity).
	2	Site (i.e. within the development property or site boundary, or the area within a few hundred meters of the site).
	3	Local (i.e. beyond the site boundary within the Local administrative boundary (e.g. Local Municipality) or within consistent local geographical features, or the area within 5 km of the site).

	4	Regional (i.e. Far beyond the site boundary, beyond the Local administrative boundaries within the Regional administrative boundaries (e.g. District Municipality), or extends into different distinct geographical features, or extends between 5 and 50 km from the site).
	5	Provincial / National / International (i.e. extends into numerous distinct geographical features, or extends beyond 50 km from the site).
Duration	1	Immediate (<1 year, quickly reversible).
	2	Short term (1-5 years, less than project lifespan).
	3	Medium term (6-15 years).
	4	Long term (15 - 65 years, the impact will cease after the operational life span of the project).
	5	Permanent (>65 years, no mitigation measure of natural process will reduce the impact after construction / operation / decommissioning).
Magnitude/ Intensity	1	Minor (where the impact affects the environment in such a way that natural, cultural and social functions and processes are not affected).
	2	Low (where the impact affects the environment in such a way that natural, cultural and social functions and processes are slightly affected, or affected environmental components are already degraded).
	3	Moderate (where the affected environment is altered but natural, cultural and social functions and processes continue albeit in a modified way; moderate improvement for +ve impacts; or where change affects area of potential conservation or other value, or use of resources).
	4	High (where natural, cultural or social functions or processes are altered to the extent that it will temporarily cease; high improvement for +ve impacts; or where change affects high conservation value areas or species of conservation concern).
	5	Very high / don't know (where natural, cultural or social functions or processes are altered to the extent that it will permanently cease, substantial improvement for +ve impacts; or disturbance to pristine areas of critical conservation value or critically endangered species).
Reversibility	1	Impact is reversible without any time and cost.
	2	Impact is reversible without incurring significant time and cost.
	3	Impact is reversible only by incurring significant time and cost.
	4	Impact is reversible only by incurring very high time and cost.
	5	Irreversible Impact.

Once the C has been determined, the significance is determined in accordance with the standard risk assessment relationship by multiplying the C and the P. Probability is rated / scored as per Table 7-2.

It is noted that both environmental risks, as well as environmental impacts, should be identified and assessed. Environmental Risk can be regarded as the potential for something harmful to happen to the environment, and in many instances is not regarded as something that is expected to occur during normal operations or events (e.g. unplanned fuel or oil spills at a construction site). Probability and likelihood are key determinants or variables of environmental risk. Environmental Impact can be regarded as the actual effect or change that happens to the environment, because of an activity and is typically an effect that is expected from normal operations or events (e.g. vegetation clearance from site development results in loss of species of concern). Typically, the probability of an unmitigated environmental impact is regarded as highly likely or certain (management and mitigation measures would ideally aim to reduce this likelihood where possible). In summary, environmental risk is about what could happen, while environmental impact is about what does happen.

Table 7-2: Probability / Likelihood Scoring

Probability	1	Improbable (Rare, the event may occur only in exceptional circumstances, the possibility of the impact materialising is very low as a result of design, historic experience, or implementation of adequate corrective actions; <5% chance).
	2	Low probability (Unlikely, impact could occur but not realistically expected; >5% and <20% chance).
	3	Medium probability (Possible, the impact may occur; >20% and <50% chance).
	4	High probability (Likely, it is most probable that the impact will occur- > 50 and <90% chance).
	5	Definite (Almost certain, the impact is expected to, or will, occur, >90% chance).

The result is a qualitative representation of relative significance associated with the impact.

Significance is therefore calculated as follows:

$$S = C \times P$$

Table 7-3: Determination of Significance

Consequence	5 Very High ¹	5	10	15	20	25
	4 High	4	8	12	16	20
	3 Medium	3	6	9	12	15
	2 Low	2	4	6	8	10
	1 Very Low	1	2	3	4	5
		1 Improbable	2 Low	3 Medium / Possible	4 High / Probable	5 Highly Likely / Definite
Probability						

The outcome of the significance assessment will result in a range of scores, ranging from 1 through to 25. These significance scores are then grouped into respective classes as described in Table 7-4.

Table 7-4: Significance Scores

Score (S)	Description
≤4.25	Low (i.e. where this impact is unlikely to be a significant environmental risk / reward).
>4.25, ≤8.5	Low-Medium (i.e. where the impact could have a significant environmental risk / reward).
>8.5, ≤13.75	High-Medium (i.e. where the impact could have a significant environmental risk / reward).
>13.75	High (i.e. where the impact will have a significant environmental risk / reward).

The impact significance will be determined for each impact without relevant management and mitigation measures (pre-mitigation significance), as well as post implementation of relevant management and mitigation measures (post-mitigation significance). This allows for a prediction in the degree to which the impact can be managed / mitigated.

¹ In the event that an impact or risk has very high or catastrophic consequences, but the likelihood / probability is low, then the resultant significance would be Low-Medium. This does in certain instances detract from the relative importance of this impact or risk and must consequently be flagged for further specific consideration, management, mitigation or contingency planning.

7.1.2 Impact Prioritization

Further to the assessment criteria presented in the section above, it is necessary to consider each potentially significant impact in terms of:

1. Cumulative impacts; and,
2. The degree to which the impact may cause irreplaceable loss of resources.

To ensure that these factors are considered, an impact prioritisation factor (PF) will be applied to each impacts' post-mitigation significance (post-mitigation). This prioritisation factor does not aim to detract from the significance ratings, but rather to focus the attention of the decision - making authority on the higher priority / significance issues and impacts. The PF will be applied to the post-mitigation significance based on the assumption that relevant suggested management / mitigation impacts are implemented.

Table 7-5: Criteria for Determining Prioritisation

Cumulative Impacts (CI)	Low (1)	Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is unlikely that the impact will result in spatial and temporal cumulative change.
	Medium (2)	Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is probable that the impact will result in spatial and temporal cumulative change.
	High (3)	Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is highly probable / definite that the impact will result in spatial and temporal cumulative change.
Irreplicable Loss of Resources (LR)	Low (1)	Where the impact is unlikely to result in irreplaceable loss of resources.
	Medium (2)	Where the impact may result in the irreplaceable loss (cannot be replaced or substituted) of resources but the value (services and / or functions) of these resources is limited.
	High (3)	Where the impact may result in the irreplaceable loss of resources of high value (services and / or functions).

The value for the final impact priority is represented as a single consolidated priority, determined as the sum of each individual criteria represented in Table 7-5. The impact priority is therefore determined as follows:

$$\text{Priority} = CI + LR$$

The result is a priority score which ranges from 2 to 6 and a consequent PF ranging from 1 to 1.5, as shown in Table 7-6.

Table 7-6: Determination of Prioritisation Factor

Priority	Prioritisation Factor
2	1
3	1.125
4	1.25
5	1.375
6	1.5

In order to determine the final impact significance (FS), the PF is multiplied by the post-mitigation significance scoring. The ultimate aim of the PF is an attempt to increase the post mitigation environmental risk rating by a factor of 0.5, if all the priority attributes are high (i.e. if an impact comes out with a high medium environmental risk after the conventional impact rating, but there is significant cumulative impact potential and significant potential for irreplaceable loss of resources, then the net result would be to upscale the impact to a higher significance).

Table 7-7: Final Environmental Significance Rating

Significance Rating	Description
<-25	Very High (Impacts in this class are extremely significant and pose a very high environmental risk. In certain instances, these may represent a fatal flaw. They are likely to have a major influence on the decision and may be difficult or impossible to mitigate. Offset's may be necessary.
<-13.75 to -25	High negative (These impacts are significant and must be carefully considered in the decision-making process. They have a high environmental risk or impact and require extensive mitigation measures).
-8.5 to -13.75	Medium-High negative (i.e. Impacts in this class are more substantial and could have a significant environmental risk. They may influence the decision to develop in the area and require more robust mitigation measures).
<-4.25 to -8.5	Medium- Low negative (i.e. These impacts are slightly more significant than low impacts but still do not pose a major environmental risk. They might require some mitigation measures but are generally manageable).
-1 to -4.25	Low negative (i.e. Impacts in this class are minor and unlikely to have a significant environmental risk. They do not influence the decision to develop in the area and are typically easily mitigated).
0	No impact

1 to 4.25	Low positive
>4.25 to <8.5	Medium-Low positive
8.5 to 13.75	Medium-High positive
>13.75	High positive

The significance ratings and additional considerations applied to each impact will be used to provide a quantitative comparative assessment of the alternatives being considered. In addition, professional expertise and opinion of the specialists and the environmental consultants will be applied to provide a qualitative comparison of the alternatives under consideration. This process will identify the best alternative for the proposed project.

7.2 Impact Assessment for the Potential Incidents

The impact of the potential incidents, is described in Table 7-8.

Table 7-8: Assessment of potential incidents

Activity	Scenario	N	E	D	M	R	C (Pre)	P (Pre)	S (Pre)	Class (Pre)	Mitigation Measures	C (Post)	P (Post)	S (Post)	Priority (CI+LR)	PF	FS	Final Class
Gas Wells (50 psig)	Catastrophic well failure (Jet fires, 1% fatality ≤ 4 m)	-1	2	2	3	2	-2.25	3	-6.75	Medium-Low	Blow-out preventers, isolation valves, exclusion zones	-1.75	2	-3.5	2	1	-3.5	Medium-Low
Pipeline (315 mm buried)	Rupture / Jet fires / Flash fires (1% fatality ≤ 68 m)	-1	3	3	3	3	-3	3	-9	Medium-High	Burial, automatic isolation, leak detection	-2.5	2	-5	4	1.3	-6.3	Medium-Low

Activity	Scenario	N	E	D	M	R	C (Pre)	P (Pre)	S (Pre)	Class (Pre)	Mitigation Measures	C (Post)	P (Post)	S (Post)	Priority	PF	FS	Final Class
Helium Storage (110 m³)	Catastrophic failure (Asphyxiant cloud, 1% fatality ≤ 62 m)	-1	3	2	3	2	-2.5	3	-7.5	Medium-Low	Ventilation, O ₂ monitoring, emergency shutdown	-2	2	-4	4	1.3	-5	Medium-Low
Helium Tanker (41 m³)	Catastrophic failure (1% fatality ≤ 44 m)	-1	3	2	3	2	-2.5	3	-7.5	Medium-Low	Loading controls, breakaway couplings	-2	2	-4	4	1.3	-5	Medium-Low

QUANTITATIVE RISK ASSESSMENT FOR THE PROPOSED D3 ENERGY PRODUCTION RIGHT ACTIVITIES ON VARIOUS FARMS NEAR VIRGINIA IN WELKOM, FREE STATE PROVINCE

Activity	Scenario	N	E	D	M	R	C (Pre)	P (Pre)	S (Pre)	Class (Pre)	Mitigation Measures	C (Post)	P (Post)	S (Post)	Priority	PF	FS	Final Class
Ammonia Refrigeration	Surge tank failure (PAC-2 = 3 032 m, PAC-3 = 699 m, 1% fatality = 255 m)	-1	5	3	4	3	-3.75	4	-15	Medium-High	Double containment, scrubbers, alarms, evacuation planning	-3	3	-9	6	1.5	-14	Medium-High

Activity	Scenario	N	E	D	M	R	C (Pre)	P (Pre)	S (Pre)	Class (Pre)	Mitigation Measures	C (Post)	P (Post)	S (Post)	Priority	PF	FS	Final Class
LNG Loading (45–60 m³)	Catastrophic tanker failure (Flash fires ≤206 m, VCE ≤125 m)	-1	4	2	4	3	-3.25	4	-13	Medium-High	Spill containment, ESD valves, exclusion zones	-2.75	3	-8.25	4	1.3	-10	Medium-High

Activity	Scenario	N	E	D	M	R	C (Pre)	P (Pre)	S (Pre)	Class (Pre)	Mitigation Measures	C (Post)	P (Post)	S (Post)	Priority	PF	FS	Final Class
CNG Storage (25 m³, 260 bar(g))	Instantaneous tank failure (Flash fires ≤206 m, VCE ≤117 m)	-1	4	3	4	3	-3.5	4	-14	Medium-High	Blast-resistant design, automatic isolation	-3	3	-9	6	1.5	-14	Medium-High
CNG Tanker (22 m³)	Instantaneous tanker failure (Flash fires ≤214 m, VCE ≤110 m)	-1	4	3	4	3	-3.5	4	-14	Medium-High	Loading controls, breakaway couplings	-3	3	-9	6	1.5	-14	Medium-High

7.3 Impact Assessment Summary

The impact assessment was undertaken by using the EIMS Significance Rating Methodology, which is aligned with the NEMA EIA Regulations (2014, as amended). The consequences were determined by using the criteria of the Nature, Extent, Duration, Magnitude and Reversibility, and the significance was calculated by multiplying consequence and probability. The final significance was determined by applying the prioritisation factor (PF), which accounts for cumulative impacts and the potential for irreplaceable loss of resources.

The assessment indicates that:

- The well and pipeline risks are spatially constrained and, following mitigation, reduce to Low-Medium significance.
- Helium releases present limited off-site consequences and remain Medium-Low after mitigation.
- Ammonia releases represent the most substantial toxic hazard, with PAC-2 distances extending up to 3 km. Mitigation reduces the final significance to Medium-High, but the activity remains a key focus area for emergency planning.
- LNG and CNG failures present high-energy fire and explosion hazards. The post-mitigation significance remains Medium-High, driven by cumulative risk and the potential for irreplaceable loss of resources.
- No scenario results in High or Very High final significance, and no fatal-flaw conditions are identified.

8 CONCLUSIONS

Risk calculations are not precise. Accuracy of predictions is determined by the quality of base data and expert judgements.

This risk assessment included the consequences of fires and explosions, as well as toxic releases at the proposed D3 Energy facilities at various farms near Virginia in Welkom. A number of well-known sources of incident data were consulted and applied to determine the likelihood of an incident to occur.

This risk assessment was performed with the assumption that each site would be maintained to an acceptable level and that all statutory regulations would be applied. It was also assumed that the detailed engineering designs would be done by competent people and would be correctly specified for the intended duty. For example, it was assumed that the tank wall thicknesses have been correctly calculated, that vents have been sized for emergency conditions, that instrumentation and electrical components comply with the specified electrical area classification, that material of construction is compatible with the products, etc.

It is the responsibility of D3 Energy and their contractors to ensure that all engineering designs would have been completed by competent persons and that all pieces of equipment would have been installed correctly. All designs should be in full compliance with (but not limited to) the Occupational Health and Safety Act 85 of 1993 and its regulations, the National Buildings Regulations and the Buildings Standards Act 107 of 1977, as well as the local by-laws.

A number of incident scenarios were simulated, taking into account the prevailing meteorological conditions, and were described in the report.

The following installations were considered for analysis in the QRA.

8.1 Hazardous Materials

The project involves several hazardous materials associated with the well drilling, gas gathering and gas processing operations. These include:

- Compressed Natural Gas (CNG) stored at 260 bar(g), capable of producing high-energy jet fires, flash fires and vapour cloud explosions (VCEs).
- Liquefied Natural Gas (LNG) stored and transported at cryogenic temperatures (-162°C), with the potential for pool fires, flash fires and VCEs.
- Helium, stored at cryogenic conditions (-269°C), non-toxic but capable of displacing oxygen and creating asphyxiant atmospheres.
- Ammonia, used in the refrigeration system, classified as *extremely toxic* by the US EPA, with PAC-2 concentrations extending up to 3 km under worst-case conditions.
- Natural gas from wells and pipelines, capable of producing jet fires and limited flash fire / VCE effects.
- Flare gas, used for the safe disposal of off-spec gas streams, producing thermal radiation and combustion emissions.

These materials require engineered containment, emergency shutdown systems, exclusion zones, and operational controls to ensure compliance with NEMA and SANS risk management principles.

8.2 Limitations and Assumptions

The risk assessment was developed based on the information provided by the client, and its engineering suppliers. These designs are conceptual and does not include detailed designs or in some cases, insufficient information to conduct a thorough risk assessment. To this end, the results obtained in this report may lack the accuracy of a detailed engineered plant. However, the risks generated are expected to represent the facility, provided that the vessel size and inventory are not increased.

These assumptions ensure that the assessment remains precautionary and aligned with the NEMA principles of risk avoidance and minimisation.

8.3 Major Hazard Installation (MHI) Tier Classification

The MHI Regulations (2022), under Chapter 1, Chapter 2 and Chapter 3, defines the establishment tier for hazardous installations. The hazardous materials stored at the gas processing plant were evaluated by using the aggregation method prescribed in the Regulations.

The aggregated hazardous inventory is below the threshold values for all tiers. Therefore, the gas processing plant is *not* a MHI Establishment under the MHI Regulations (2022).

The gas gathering pipeline system is **not** classified as Major Hazard Establishment under Chapter 3.

8.4 Well Drilling and Gathering Pipeline

The wellfield comprises of 43 wells, including 13 new wells and 3 existing wells positioned along the Virginia Fault. These wells operate at a relatively low pressure of 50 psig, resulting in highly localised consequence distances. The modelling confirms that a catastrophic well failure would generate a vertical jet fire with a 1% fatality distance of approximately 4 m, while flash fire and vapour cloud explosion (VCE) effects are negligible. This demonstrates that well-related risks are spatially constrained and do not pose off-site fatality risks.

The 315 mm buried gathering pipeline exhibits similarly limited consequence distances. A full-bore rupture could produce a jet fire extending up to 68 m, a flash fire of 4 m, and a VCE of 9 m. These distances remain completely within the pipeline servitude, and no residential areas fall within the impact zones. Burial of the pipeline, sectional isolation valves, and leak detection systems further reduce the likelihood and consequence of such events.

Overall, the wellfield and gathering pipeline present low to medium-low residual risks, with impacts restricted to operational areas and no potential for off-site fatalities.

8.5 Gas Processing Plant

8.5.1 Compressed Natural Gas (CNG)

CNG is stored at 260 bar(g) in high-pressure vessels and transported via 22 m³ road tankers. Consequence modelling indicates that a catastrophic failure could result in flash fire distances of 206 m - 214 m and VCE distances of 110 m - 117 m. These distances may extend toward the R73 road, but remain within acceptable industrial land-use thresholds.

Engineering controls such as blast-resistant design, automatic isolation valves, and breakaway couplings significantly reduce the likelihood of such events.

Residual significance remains medium-high, driven primarily by the high-energy nature of compressed gas releases.

8.5.2 Liquefied Natural Gas (LNG)

LNG tanker failures present cryogenic and flammable hazards. A catastrophic release may generate a pool fire of 145 m, a flash fire of 206 m, and a VCE of 125 m. Flash fire effects dominate the 1% fatality boundary. Importantly, all consequence distances remain within the gas processing plant boundary, and no residential receptors fall within the impact zones. Proper cryogenic containment, ESD systems, and exclusion zones during loading ensure that LNG-related risks remain medium-high, but manageable.

8.5.3 Helium

Helium releases, although non-toxic, can displace oxygen and create asphyxiant conditions. Catastrophic failures of storage tanks or tankers produce 1% fatality distances of 44 m - 62 m, all of which remain fully confined to the plant boundary. Helium impacts therefore present medium-low residual significance, with risks mitigated through ventilation, oxygen monitoring, and cryogenic equipment integrity controls.

8.5.4 Flare System

The flare system is designed for controlled disposal of off-spec gas streams. Impacts include thermal radiation, combustion emissions, and noise, all of which remain within the plant boundary. With proper design in accordance with suitable standards, flare-related impacts are considered low-medium and do not pose off-site risks.

8.6 Impacts onto Neighbouring Properties

The results of the consequence modelling clearly demonstrate that no fatality-level impacts extend into any neighbouring residential areas under any of the credible worst-case scenarios assessed. All high-energy events associated with well failures, pipeline ruptures, CNG and LNG releases, helium releases, and flare operation remain spatially constrained within the project's operational footprint or immediate servitude.

The only endpoint that extends meaningfully off-site is the ammonia PAC-2 concentration, which may reach distances of up to 3 km under worst-case meteorological conditions. While this represents the maximum downwind distance at which individuals may experience irreversible or serious health effects, the modelling confirms that no fatalities are expected, and the PAC-3 and 1% fatality zones remain well within the plant boundary. This ensures that residential receptors are not exposed to life-threatening concentrations.

High-pressure gas systems - specifically CNG and LNG storage and tanker loading - produce flash fire and VCE distances that may extend toward the R73 road, but these remain within acceptable industrial risk thresholds and do not encroach upon sensitive land uses. The impacts are significant from an engineering perspective, but are effectively managed through exclusion zones, blast-resistant design, automatic isolation systems, and emergency shutdown procedures.

The wellfield and gathering pipeline present the lowest off-site risk profile. Consequence distances for wells (jet fire ~4 m) and pipelines (jet fire 68 m, flash fire 4 m, VCE 9 m) remain fully confined to the designated servitude, with no potential to affect residential areas or public infrastructure. Their low operating pressures and buried configuration further reduce off-site exposure.

Similarly, helium releases - although capable of creating oxygen-deficient atmospheres - produce 1% fatality distances of only 44 m - 62 m, all of which remain within the gas processing plant boundary. Helium therefore poses no off-site fatality risk.

The flare system, designed for controlled combustion of off-spec gas, generates thermal radiation, combustion emissions, and noise, but all impacts remain within the site boundary and do not affect neighbouring properties. Proper flare design in accordance with SANS 10089-2 ensures that flare-related risks remain low.

Taken together, the assessment confirms that the project does not pose unacceptable off-site risks and does not trigger fatal-flaw conditions under NEMA, the MHI Regulations (2022), or associated SANS standards. All significant impacts are either fully contained within the operational footprint or mitigated to levels consistent with industrial land-use planning requirements. The project is therefore considered environmentally viable from a risk and safety perspective.

8.7 Maximum Individual Risks

The combined site individual risk assessment integrates the full suite of consequence modelling results with the frequency analysis. Individual risk represents the probability of fatality for a hypothetical person continuously present at a specific location (24 hours per day, 365 days per year). Although this assumption overstates real-world exposure, it is intentionally conservative and widely accepted for land-use planning and regulatory compliance.

The individual risk contours shown in demonstrate a clear and favourable risk envelope around the facility. However, road crossings along the gas gathering pipeline routes require special attention during detailed design, construction and operation, and additional mitigation may be required at these locations. Each crossing should be subject to a site-specific assessment that considers traffic loading, burial depth, pipe protection, third-party interference and emergency access. Appropriate measures may include increased cover or protective sleeves, clearly marked crossing points, controlled excavation procedures, suitable isolation and leak-detection arrangements, and coordination with the relevant road authority. Crossings of higher-traffic roads should be prioritised for enhanced inspection and integrity monitoring because a loss of containment at these locations could expose road users and complicate emergency response.

Overall, the individual risk assessment confirms that no fatality-level risks extend off-site, and that all residential and public receptors remain within acceptable or trivial risk zones. **The only area requiring targeted mitigation is the LNG-related worker risk envelope, which can be reduced to acceptable levels through engineering and operational controls.**

The alternative pipeline routing, is shown in Figure 3-3. Road crossings along the gas gathering pipeline routes require special attention during detailed design, construction and operation, and additional mitigation may be required at these locations. Each crossing should be subject to a site-specific assessment that considers traffic loading, burial depth, pipe protection, third-party interference and emergency access.

Appropriate measures may include increased cover or protective sleeves, clearly marked crossing points, controlled excavation procedures, suitable isolation and leak-detection arrangements, and coordination with the relevant road authority. Crossings of higher-traffic roads should be prioritised for enhanced inspection and integrity monitoring because a loss of containment at these locations could expose road users and complicate emergency response.

Future land-use planning must continue to reference the PADHI tables to ensure compatibility with the established risk envelope.

9 RECOMMENDATIONS

RISCOM did not find any fatal flaws that would prevent the project proceeding to the detailed engineering phase of the project.

RISCOM supports the project with the following conditions:

- Compliance with all applicable statutory requirements, including the design, registration, manufacture, inspection, testing and certification of pressure equipment by competent persons in accordance with the Occupational Health and Safety Act, the Pressure Equipment Regulations and the applicable conformity-assessment requirements;
- Compliance with applicable SANS codes, i.e., SANS 10087, SANS 10089, SANS 10108, etc.;
- Incorporation of applicable guidelines or equivalent international recognised codes of good design and practice into the designs;
- Completion of a recognised process hazard analysis (such as a HAZOP study, FMEA, etc.) on the proposed facility prior to construction to ensure that design and operational hazards have been identified and that adequate mitigation is put in place;
- Application of IEC 61508 and IEC 61511 for safety instrumented systems, or equivalent recognised standards, where the process hazard analysis identifies instrumented protection, as necessary. The required safety functions, integrity targets, independence, reliability, testing, maintenance and management arrangements must be defined and maintained throughout the facility life cycle:
 - The designer must provide documented verification that the protective instrumentation is sufficient, suitably independent and reliable for the identified hazards and is correctly specified, installed, commissioned, proof-tested and maintained;
- Preparation and issue of a safety basis document during the detailed design, describing the design features, safeguards and management measures that reduce the consequences of fires, explosions, flammable or toxic releases and oxygen-deficient atmospheres. The document must be completed before construction, updated to reflect the as-built facility and retained as a controlled life-cycle document:
 - Demonstration of compliance with applicable legislation, codes and standards and recognised good engineering practice;
 - Including the listing of statutory and non-statutory inspections, giving frequency of inspections; and,
 - An independent audit of the as-built facility against the approved safety basis before commissioning, with identified deviations assessed, documented and closed out.
- Noting that codes, such as IEC 61511 can be used to achieve these requirements;
- Verification during detailed design, using complete engineering information and final maximum hazardous-material inventories, that the aggregation value remains below the lower-tier threshold and that the gas gathering pipelines do not meet the Chapter 3 criteria. The assessment and supporting calculations must be documented and reviewed by a competent process-safety practitioner. If the final design, inventories, containment arrangements or operating conditions cause any applicable threshold or Chapter 3 criterion to be met or exceeded, the MHI Regulations (2022) must be applied and an MHI risk assessment must be undertaken by an Approved Inspection Authority before construction or operation, as applicable;

- Signature of all designs by a professional engineer registered in South Africa in accordance with the Professional Engineers Act, who takes responsibility for suitable designs;
- Completion of an emergency preparedness and response document for credible on-site and off-site scenarios before commissioning, with appropriate consultation with local emergency services and authorities;
- Submission of the final design safety basis and documented tier-reassessment outcome to the relevant local government authority as part of the applicable approval process (where applicable). Based on the current design information, the facility falls below the lower-tier threshold and is not classified as a Major Hazard Establishment. An MHI risk assessment and registration will therefore only be required if the final design, maximum hazardous-material inventories, containment arrangements, operating conditions or pipeline design trigger an applicable threshold or Chapter 3 criterion:
 - The final verification must be based on the completed design and maximum credible inventories and must account for all engineering safeguards and mitigations.

10 REFERENCES

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11 ABBREVIATIONS AND ACRONYMS

AA	“Advised Against” used in land planning decisions.
AEGL	Acute exposure guideline levels are values published by the US Environmental Protection Agency (EPA). AEGL values represent threshold exposure limits for the general public applicable to five emergency exposure periods (10 minutes, 30 minutes, 1 hour, 4 hours and 8 hours) and are distinguished by varying degrees of severity of toxic effects. AEGL-1 is the airborne concentration of a substance above which it is predicted that the general population, including susceptible individuals, could experience notable discomfort, irritation or certain asymptomatic non-sensory effects. However, the effects are not disabling and are transient and reversible upon cessation of exposure. AEGL-2 is the airborne concentration of a substance above which it is predicted that the general population, including susceptible individuals, could experience irreversible or other serious, long lasting adverse health effects or an impaired ability to escape. AEGL-3 is the airborne concentration of a substance above which it is predicted that the general population, including susceptible individuals, could experience life-threatening health effects or death. Although the AEGL values represent threshold levels for the general public, including susceptible subpopulations, such as infants, children, the elderly, persons with asthma and those with other illnesses, it is recognized that individuals, subject to unique or idiosyncratic responses, could experience the effects described at concentrations below the corresponding AEGL value.
AIA	See Approved Inspection Authority
A schedule of statutory and non-statutory inspections, tests and audits, including responsible persons, acceptance criteria and required frequencies;	The UK Health and Safety Executive (HSE) developed the risk ALARP triangle, in an attempt to account for risks in a manner similar to those used in everyday life. This involved deciding: Whether a risk is so high that something must be done about it; Whether the risk is or has been made so small that no further precautions are necessary; Whether a risk falls between these two states and has been reduced to levels ‘as low as reasonably practicable’ (ALARP). Reasonable practicability involves weighing a risk against the trouble, time and money needed to control it.
API	The American Petroleum Institute is the largest U.S. trade association for the oil and natural gas industry. It claims to represent nearly 600 corporations involved in production, refinement, distribution, and many other aspects of the petroleum industry.
Approved Inspection Authority	An approved inspection authority (AIA) is defined in the Major Hazard Installation regulations (2022).
Asphyxiant	An asphyxiant is a gas that is nontoxic but may be fatal if it accumulates in a confined space and is breathed at high concentrations since it replaces oxygen containing air.

Blast Overpressure	Blast overpressure is a measure used in the multi-energy method to indicate the strength of the blast, indicated by a number ranging from 1 (for very low strengths) up to 10 (for detonative strength).
BLEVE	Boiling liquid expanding vapour explosions result from the sudden failure of a vessel containing liquid at a temperature above its boiling point. A BLEVE of flammables results in a large fireball.
CBL	A Cement Bond Log (CBL) is an acoustic well-logging tool used in the oil and gas industry to evaluate the integrity of the cement sheath behind the steel casing. It measures the amplitude of sound waves to verify proper zonal isolation and prevent fluid migration between different rock layers.
CNG	Compressed natural gas (CNG) (methane stored at high pressure) is a fuel that can be used in place of gasoline, diesel fuel and liquefied petroleum gas (LPG). CNG combustion produces fewer undesirable gases than the aforementioned fuels. In comparison to other fuels, natural gas poses less of a threat in the event of a spill, because it is lighter than air and disperses quickly when released. Biomethane — refined biogas from anaerobic digestion or landfills — can be used.
DAA	“Don’t Advise Against” used in land planning decisions.
Deflagration	Deflagration is a chemical reaction of a substance, in which the reaction front advances into the unreacted substance at less than sonic velocity.
Detonation	Detonation is a release of energy caused by extremely rapid chemical reaction of a substance, in which the reaction front of a substance is determined by compression beyond the auto-ignition temperature.
Emergency Plan	An emergency plan is a plan in writing that describes how potential incidents identified at the installation together with their consequences should be dealt with, both on site and off site.
ER	An exploration right is a legal, limited real right granted by the state that permits the holder to enter, survey, and scientifically test a specific tract of land to determine the presence, volume, and commercial viability of underground natural resources like petroleum, gas, or minerals. It does not convey ownership of the land or the right to extract resources commercially.
ERPG	Emergency response planning guidelines were developed by the American Industrial Hygiene Association. ERPG-1 is the maximum airborne concentration below which it is believed nearly all individuals could be exposed for up to 1 hour without experiencing anything other than mild transient adverse health effects or perceiving a clearly defined objectionable odour. ERPG-2 is the maximum airborne concentration below which it is believed nearly all individuals could be exposed for up to 1 hour without experiencing or developing irreversible or other serious health effects or symptoms that could impair their abilities to take protective action. ERPG-3 is the maximum airborne concentration below which it is believed nearly all individuals could be exposed for up to 1 hour without experiencing or developing life-threatening health effects.
ESD	Emergency Shut Down (ESD) is designed to minimize the consequences of emergency situations, related to typically

	uncontrolled flooding, escape of hydrocarbons, or outbreak of fire in hydrocarbon carrying areas or areas which may otherwise be hazardous.
Explosion	An explosion is a release of energy that causes a pressure discontinuity or blast wave.
Flammable Limits	Flammable limits are a range of gas or vapour concentrations in the air that will burn or explode if a flame or other ignition source is present. The lower point of the range is called the lower flammable limit (LFL). Likewise, the upper point of the range is called the upper flammable limit (UFL).
Flammable Liquid	The Occupational Health and Safety Act 85 of 1993 defines a flammable liquid as any liquid which produces a vapour that forms an explosive mixture with air and includes any liquid with a closed cup flashpoint of less than 55°C. Flammable products have been classified according to their flashpoints and boiling points, which ultimately determine the propensity to ignite. Separation distances described in the various codes are dependent on the flammability classification. Class Description 0 Liquefied natural gas (LNG) IA Liquids that have a closed cup flashpoint of below 23°C and a boiling point below 35°C IB Liquids that have a closed cup flashpoint of below 23°C and a boiling point of 35°C or above IC Liquids that have a closed cup flashpoint of 23°C and above but below 38°C II Liquids that have a closed cup flashpoint of 38°C and above but below 60.5°C IIA Liquids that have a closed cup flashpoint of 60.5°C and above but below 93°C
Flash Fire	A flash fire is defined as combustion of a flammable vapour and air mixture in which the flame passes through the mixture at a rate less than sonic velocity so that negligible damaging overpressure is generated.
FMEA	Failure mode and effects analysis is the process of reviewing as many components, assemblies, and subsystems as possible to identify potential failure modes in a system and their causes and effects
Frequency	Frequency is the number of times an outcome is expected to occur in a given period of time.
HAZOP	A hazard and operability study (HAZOP) are a structured and systematic examination of a complex planned or existing process or operation in order to identify and evaluate problems that may represent risks to personnel or equipment.
HDPE	High-density polyethylene (HDPE) pipe is a flexible, highly durable plastic pipe used globally for potable water supply, agricultural irrigation, and industrial plumbing. Lightweight and corrosion-resistant, it is available in various pressure ratings (e.g., Class 6, 10, 12, 16) and coil lengths.
HEL	The highest concentration of a gas or vapor (percentage by volume in air) above which a flame will not spread in the presence of an

	ignition source (arc, flame, or heat). Concentrations higher than UEL are “too rich” to burn. Also called upper flammable limit (UFL).
IDLH	Immediately dangerous to life or health values were developed by the National Institute of Occupational Safety and Health (NIOSH). IDLH value refers to a maximum concentration to which a healthy person may be exposed for 30 minutes and escape without suffering irreversible health effects or symptoms that impair escape (ranging from runny eyes that temporarily impair eyesight to a coma). IDLH values are intended to ensure that workers can escape from a given contaminated environment in the event of failure of the respiratory protection equipment.
Ignition Source	An ignition source is a source of temperature and energy sufficient to initiate combustion.
Individual Risk	Individual risk is the probability that in one year a person will become a victim of an accident if the person remains permanently and unprotected in a certain location. Often the probability of occurrence in one year is replaced by the frequency of occurrence per year.
	See Risk Isopleth
Jet	A jet is the outflow of material emerging from an orifice with significant momentum.
Jet Fire or Flame	A jet fire or flame is combusting material emerging from an orifice with a significant momentum.
LFL	Lower Flammable Limit see Flammable Limits
LC	Lethal concentration is the concentration by which a given percentage of the exposed population will be fatally injured. The LC ₅₀ refers to the concentration of airborne material the inhalation of which results in death of 50% of the test group. The period of inhalation exposure could be from 30 min to a few hours (up to 4 hours).
LD	In toxicology, the lethal dose is an indication of the lethal toxicity of a given substance or type of radiation. Because resistance varies from one individual to another, the "lethal dose" represents a dose at which a given percentage of subjects will die.
LEL	Lower Explosive Limit , is defined as the lowest concentration (by percentage) of a gas or vapor in air that is capable of producing a flash of fire in presence of an ignition source (arc, flame, heat). ... In concentrations of 0% - 5% Methane in air, the mixture is too lean to ignite or burn.
LNG	Liquefied natural gas (LNG) is natural gas (predominantly methane, CH ₄ , with some mixture of ethane, C ₂ H ₆) that has been cooled down to liquid form for ease and safety of non-pressurized storage or transport.
LO	In the context of power generation and large dual-fuel or gas engines (such as marine or industrial engines), LO refers to Lubricating Oil , while Fuel Oil (often categorized as LFO for Light Fuel Oil or HFO for Heavy Fuel Oil) serves as the primary or back-up fuel .
LOC	See Loss of Containment
Local Government	Local government is defined in Section 1 of the Local Government Transition Act, 1993 (Act No. 209 of 1993).

Loss of Containment	Loss of containment (LOC) is the event resulting in a release of material into the atmosphere.
Major Hazard Installation	Major Hazard Installation (MHI) means an installation: Where more than the prescribed quantity of any substance is or may be kept, whether permanently or temporarily; Where any substance is produced, used, handled or stored in such a form and quantity that it has the potential to cause a major incident (the potential of which will be determined by the risk assessment).
Major Incident	A major incident is an occurrence of catastrophic proportions, resulting from the use of plant or machinery or from activities at a workplace. When the outcome of a risk assessment indicates that there is a possibility that the public will be involved in an incident, then the incident is catastrophic.
Material Safety Data Sheet	According to ISO-11014, a Material Safety Data Sheet (MSDS) is a document that contains information on the potential health effects of exposure to chemicals or other potentially dangerous substances and on safe working procedures when handling chemical products. It is an essential starting point for the development of a complete health and safety program. It contains hazard evaluations on the use, storage, handling and emergency procedures related to that material. An MSDS contains much more information about the material than the label and it is prepared by the supplier. It is intended to tell what the hazards of the product are, how to use the product safely, what to expect if the recommendations are not followed, what to do if accidents occur, how to recognize symptoms of overexposure and what to do if such incidents occur.
MHI	See Major Hazard Installation
MIR	Maximum Individual Risk (see Individual Risk)
MMSCFD	MMSCFD stands for Million Standard Cubic Feet per Day . It is a standardized volumetric flow rate unit widely used in the oil and gas industry to measure large quantities of natural gas, compressed natural gas, or liquefied petroleum gas.
MSDS	See Material Safety Data Sheet
NEMA	National Environmental Management Act
NOVO	A NOVO tube trailer is a specialized transport vehicle used to haul bulk quantities of compressed gases, such as hydrogen, nitrogen, or helium. It features multiple long, horizontal steel cylinders (tubes) manifolded together to act as a single high-capacity storage and distribution system.
OHS Act	Occupational Health and Safety Act, 1993 (Act No. 85 of 1993)
PAC	See Protective Action Criteria
PADHI	PADHI (Planning Advice for Developments near Hazardous Installations) is the name given to a methodology and software decision support tool developed and used in the HSE. It is used to give land-use planning (LUP) advice on proposed developments near hazardous installations. PADHI uses two inputs into a decision matrix to generate either an 'advise against' or 'don't advise against' response: The zone in which the development is located of the three zones that HSE sets around the major hazard:

	The inner zone ($> 1 \times 10^{-5}$ fatalities per person per year); The middle zone (1×10^{-5} fatalities per person per year to 1×10^{-6} fatalities per person per year); The outer zone (1×10^{-6} fatalities per person per year to 3×10^{-7} fatalities per person per year); The 'sensitivity level' of the proposed development which is derived from an HSE categorisation system of 'development types' (see the 'development type tables' in Appendix C).
PHA	A process hazard analysis is a set of organized and systematic assessments of the potential hazards associated with an industrial process.
POST	The Parliamentary Office of Science and Technology is the Parliament of the United Kingdom's in-house source of independent, balanced and accessible analysis of public policy issues related to science and technology.
PPE	Personal Protective Equipment , commonly referred to as "PPE", is equipment worn to minimize exposure to hazards that cause serious workplace injuries and illnesses.
PPM	This is an abbreviation for " parts per million " and it also can be expressed as milligrams per liter (mg/L). This measurement is the mass of a chemical or contaminate per unit volume of water.
PR	Production rights are the legal permissions or licenses required to create, stage, broadcast, or manufacture a creative, digital, or physical work. They give a person or company the authorized power to bring a project—such as a play, film, software, or musical recording—to an audience or market place.
Protective Action Criteria	Protective action criteria (PAC) for emergency planning of chemical release events are based on the following chemical exposure limit values: Acute exposure guideline level (AEGL) values published by the US Environmental Protection Agency (EPA); Emergency response planning guideline (ERPG) values produced by the American Industrial Hygiene Association (AIHA); Temporary emergency exposure limit (TEEL) values developed by the Subcommittee on Consequence Assessment and Protective Actions (SCAPA).
PSA	Pressure Swing Adsorption (PSA) is an industrial process used to separate and purify specific gases from a mixture. By cycling between high and low pressures, the system traps target gases on porous materials—like zeolite or activated carbon—while allowing others to pass through.
QRA	See Quantitative Risk Assessment
Quantitative Risk Assessment	A quantitative risk assessment is the process of hazard identification, followed by a numerical evaluation of effects of incidents, both consequences and probabilities and their combination into the overall measure of risk.
Risk	Risk is the measure of the consequence of a hazard and the frequency at which it is likely to occur. Risk is expressed mathematically as: Risk = Consequence x Frequency of Occurrence

Risk Assessment	Risk assessment is the process of collecting, organising, analysing, interpreting, communicating and implementing information in order to identify the probable frequency, magnitude and nature of any major incident which could occur at a major hazard installation and the measures required to remove, reduce or control potential causes of such an incident.
Risk Contour	See Risk Isopleth
SANAS	The South African National Accreditation System (SANAS) is the only national body responsible for carrying out accreditations in respect of conformity assessment, as mandated through the Accreditation for Conformity Assessment, Calibration and Good Laboratory Practice Act (Act 19 of 2006).
SIL	The Safety Integrity Level is a numeric value that represents an overall rating for the instrumented function. This rating tells you to what degree the instrumented function meets its requirements to mitigate risk.
Societal Risk	Societal risk is risk posed on a societal group who are exposed to a hazardous activity.
TD	In the oil, gas, and drilling industries, Total Depth (TD) is the maximum vertical or measured downward length of a wellbore. It is commonly categorized into Measured Depth (along the actual well path) and True Vertical Depth (the straight-line distance from the rig floor to the bottom).
Temporary Installation	A temporary installation is an installation that can travel independently between planned points of departure and arrival for the purpose of transporting any substance and which is only deemed to be an installation at the points of departure and arrival, respectively.
TLV-STEL	Short-term exposure threshold limit values are the concentrations to which workers can be exposed continuously for a short period (15 minutes) of time without suffering from irritation, chronic or irreversible tissue damage or narcosis to a sufficient degree to increase the likelihood of accidental injury, impair self-rescue or materially reduce work efficiency, provided that the daily TLV-TWA is not exceeded.
TLV-TWA	Time weighted average threshold limit values are the concentrations for a normal 8-hour workday and a 40-hour workweek, to which nearly all workers may be repeatedly exposed day after day, without adverse effects.
UFL	Upper Flammable Limit (see Flammable Limits)
Vapour Cloud Explosion	A Vapour Cloud Explosion (VCE) results from ignition of a premixed cloud of a flammable vapour, gas or spray with air, in which flames accelerate to sufficiently high velocities to produce significant overpressure.
VCE	See Vapour Cloud Explosion

12 APPENDIX A: SPECIALIST DECLARATION

		SPECIALIST DECLARATION	
EIMS Ref	EIMS Project #	Project Name	D3 ENERGY PRODUCTION RIGHT ACTIVITIES ON VARIOUS FARMS NEAR VIRGINIA IN WELKOM, FREE STATE PROVINCE

Project Details

Project Name	D3 ENERGY PRODUCTION RIGHT ACTIVITIES ON VARIOUS FARMS NEAR VIRGINIA IN WELKOM, FREE STATE PROVINCE
Applicant	
Competent Authority	

Specialist Details

Specialist Company	Riscom (Pty) Ltd		
Specialist Name	Michael Oberholzer		
Contact details	Tel		Cell +27824573258
	E-mail	mike@riscom.co.za	
	Postal Address	541 Heron Place, Maroeladal, Randburg 2191	
	Physical Address	Postnet Suite 010, Private Bag X153, Bryanston 2021	

General Declaration

By signing this form, I hereby declare that:

- I act as an independent specialist in this application.
- I will perform the work relating to the application in an objective manner, even if this results in views and findings that are not favourable to the applicant.
- I declare that there are no circumstances that may compromise my objectivity in performing such work.
- I have expertise in conducting undertaking the specialist work as required, including knowledge of the Act, Regulations and any guidelines that have relevance to the proposed activity.
- I will comply with the Act, Regulations, and all other applicable legislation.
- I have not, and will not engage in, conflicting interest in the undertaking of the activity.
- I understand to disclose to the applicant and competent authority all material information in my possession that reasonably has or may have the potential of influencing any decision to be taken with respect to the application by the competent authority; and the objectivity of any report, plan or document to be prepared by myself for submission to the competent authority.
- I have taken into account, to the extent possible, the matters referred to in Regulation 18 when preparing the report, plan or document.
- I will provide the competent authority with access to all information at my disposal regarding the application, whether such information is favourable to the applicant or not.
- All the particulars furnished by me this form are true and correct.

Page 1 of 2

A 8 Dalmeny Road, Pine Park, Randburg	E mail@eims.co.za W www.eims.co.za F (085) 571- 9047 T (011) 789-7170 P PO Box 2083, Pnengowrie 2123, South Africa
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 EIMS ENVIRONMENTAL IMPACT MANAGEMENT SERVICES		SPECIALIST DECLARATION	
EIMS Ref	EIMS Project #	Project Name	D3 ENERGY PRODUCTION RIGHT ACTIVITIES ON VARIOUS FARMS NEAR VIRGINIA IN WELKOM, FREE STATE PROVINCE

- I will perform all other obligations as expected from an environmental assessment practitioner in terms of the Regulations.
- I am aware of what constitutes an offence in terms of Regulation 48 and that a person convicted of an offence in terms of Regulation 48(1) is liable to the penalties as contemplated in Section 49B of the Act.

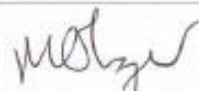
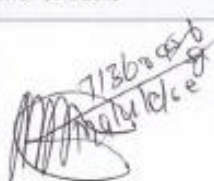
Disclosure of Vested Interest

- I do not have and will not have any vested interest (either business, financial, personal or other) in the proposed activity proceeding other than remunerative for work performed in terms of the Regulations.

Undertaking Under Oath/Affirmation

By signing this form, I swear under oath/affirm that all the information submitted or to be submitted for the purposes of this application is true and correct.

Signatures

Specialist					
Name	Michael Oberholzer	Signature		Date	15/9/2026
Commissioner of Oaths					
Name		Signature		Date	2026/09/15

Commissioner of Oaths Official Stamp



Page 2 of 2

13 APPENDIX B: MHI REGULATIONS (2022)

14 APPENDIX C: PADHI LAND-PLANNING TABLES

14.1 Development Type Table 1: People at Work, Parking

Development Type	Examples	Development Detail and Size	Justification
DT1.1 Workplaces	Offices, factories, warehouses, haulage depots, farm buildings, nonretail markets, builder's yards	Workplaces (predominantly nonretail), providing for less than 100 occupants in each building and less than 3 occupied storeys (Level 1)	Places where the occupants will be fit and healthy and could be organised easily for emergency action Members of the public will not be present or will be present in very small numbers and for a short time
	Exclusions		
		DT1.1 x1 Workplaces (predominantly nonretail) providing for 100 or more occupants in any building or 3 or more occupied storeys in height (Level 2 except where the development is at the major hazard site itself, where it remains Level 1)	Substantial increase in numbers at risk with no direct benefit from exposure to the risk
	Sheltered workshops, Remploy	DT1.1 x2 Workplaces (predominantly nonretail) specifically for people with disabilities (Level 3)	Those at risk may be especially vulnerable to injury from hazardous events or they may not be able to be organised easily for emergency action
DT1.2 Parking Areas	Car parks, truck parks, lockup garages	Parking areas with no other associated facilities (other than toilets; Level 1)	
	Exclusions		
	Car parks with picnic areas or at a retail or leisure development or serving a park and ride interchange	DT1.2 x1 Where parking areas are associated with other facilities and developments the sensitivity level and the decision will be based on the facility or development	

14.2 Development Type Table 2: Developments for Use by the General Public

Development Type	Examples	Development Detail and Size	Justification
DT2.1 Housing	Houses, flats, retirement flats or bungalows, residential caravans, mobile homes	Developments up to and including 30 dwelling units and at a density of no more than 40 per hectare (Level 2)	Development where people live or are temporarily resident It may be difficult to organise people in the event of an emergency
	Exclusions		
	Infill, back-land development	DT2.1 x1 Developments of 1 or 2 dwelling units (Level 1)	Minimal increase in numbers at risk
	Larger housing developments	DT2.1 x2 Larger developments for more than 30 dwelling units (Level 3)	Substantial increase in numbers at risk
		DT2.1 x3 Any developments (for more than 2 dwelling units) at a density of more than 40 dwelling units per hectare (Level 3)	High-density developments
DT2.2 Hotel or Hostel or Holiday Accommodation	Hotels, motels, guest houses, hostels, youth hostels, holiday camps, holiday homes, halls of residence, dormitories, accommodation centres, holiday caravan sites, camping sites	Accommodation up to 100 beds or 33 caravan or tent pitches (Level 2)	Development where people are temporarily resident It may be difficult to organise people in the event of an emergency
	Exclusions		
	Smaller: guest houses, hostels, youth hostels, holiday homes, halls of residence, dormitories, holiday caravan sites, camping sites	DT2.2 x1 Accommodation of less than 10 beds or 3 caravan or tent pitches (Level 1)	Minimal increase in numbers at risk
	Larger: hotels, motels, hostels, youth hostels, holiday camps, holiday homes, halls of residence, dormitories, holiday	DT2.2 x2 Accommodation of more than 100 beds or 33 caravan or tent pitches (Level 3)	Substantial increase in numbers at risk

Development Type	Examples	Development Detail and Size	Justification
	caravan sites, camping sites		
DT2.3 Transport Links	Motorway, dual carriageway	Major transport links in their own right i.e. not as an integral part of other developments (Level 2)	Prime purpose is as a transport link Potentially large numbers exposed to risk but exposure of an individual is only for a short period
	Exclusions		
	Estate roads, access roads	DT2.3 x1 Single carriageway roads (Level 1)	Minimal numbers present and mostly a small period of time exposed to risk Associated with other development
	Any railway or tram track	DT2.3 x2 Railways (Level 1)	Transient population, small period of time exposed to risk Periods of time with no population present

Development Type	Examples	Development Detail and Size	Justification
DT2.4 Indoor Use by Public	Food and drink: restaurants, cafes, drive-through fast food, pubs Retail: shops, petrol filling station (total floor space based on shop area not forecourt), vehicle dealers (total floor space based on showroom or sales building not outside display areas), retail warehouses, super-stores, small shopping centres, markets, financial and professional services to the public Community and adult education: libraries, art galleries, museums, exhibition halls, day surgeries, health centres, religious buildings, community centres. adult education, 6th form college, college of FE Assembly and leisure: Coach or bus or railway stations, ferry terminals, airports, cinemas, concert or bingo or dance halls, conference centres, sports or leisure centres, sports halls, facilities associated with golf courses, flying clubs (e.g. changing rooms, club house), indoor go kart tracks	Developments for use by the general public where total floor space is from 250 m ² up to 5000 m ² (Level 2)	Developments where members of the public will be present (but not resident) Emergency action may be difficult to coordinate
	Exclusions		
		DT2.4 x1 Development with less than 250 m ² total floor space (Level 1)	Minimal increase in numbers at risk
		DT2.4 x2 Development with more than 5000 m ² total floor space (Level 3)	Substantial increase in numbers at risk
DT2.5 Outdoor Use by Public	Food and drink: food festivals, picnic areas	Principally an outdoor development for use by the general public	Developments where members of the public will

Development Type	Examples	Development Detail and Size	Justification
	Retail: outdoor markets, car boot sales, funfairs Community and adult education: open-air theatres and exhibitions Assembly and leisure: coach or bus or railway stations, park and ride interchange, ferry terminals, sports stadia, sports fields or pitches, funfairs, theme parks, viewing stands, marinas, playing fields, children's play areas, BMX or go kart tracks, country parks, nature reserves, picnic sites, marquees	i.e. developments where people will predominantly be outdoors and not more than 100 people will gather at the facility at any one time (Level 2)	be present (but not resident) either indoors or outdoors Emergency action may be difficult to coordinate
	Exclusions		
	Outdoor markets, car boot sales, funfairs picnic area, park and ride interchange, viewing stands, marquees	DT2.5 x1 Predominantly open-air developments likely to attract the general public in numbers greater than 100 people but up to 1000 at any one time (Level 3)	Substantial increase in numbers at risk and more vulnerable due to being outside
	Theme parks, funfairs, large sports stadia and events, open air markets, outdoor concerts, pop festivals	DT2.5 x2 Predominantly open-air developments likely to attract the general public in numbers greater than 1000 people at any one time (Level 4)	Very substantial increase in numbers at risk, more vulnerable due to being outside Emergency action may be difficult to coordinate

14.3 Development Type Table 3: Developments for Use by Vulnerable People

Development Type	Examples	Development Detail and Size	Justification
DT3.1 Institutional Accommodation and Education	Hospitals, convalescent homes, nursing homes, old people's homes with warden on site or 'on call', sheltered housing, nurseries, crèches, schools and academies for children up to school leaving age	Institutional, educational and special accommodation for vulnerable people or that provides a protective environment (Level 3)	Places providing an element of care or protection Because of age, infirmity or state of health the occupants may be especially vulnerable to injury from hazardous events Emergency action and evacuation may be very difficult
	Exclusions		
	Hospitals, convalescent homes, nursing homes, old people's homes, sheltered housing	DT3.1 x1 24-hour care where the site on the planning application being developed is larger than 0.25 hectare (Level 4)	Substantial increase in numbers of vulnerable people at risk
	Schools, nurseries, crèches	DT3.1 x2 Day care where the site on the planning application being developed is larger than 1.4 hectare (Level 4)	Substantial increase in numbers of vulnerable people at risk
DT3.2 Prisons	Prisons, remand centres	Secure accommodation for those sentenced by court, or awaiting trial, etc. (Level 3)	Places providing detention Emergency action and evacuation may be very difficult

14.4 Development Type Table 4: Very Large and Sensitive Developments

Development Type	Examples	Development Detail and Size	Justification
Note: all Level 4 developments are by exception from Level 2 or 3 and are reproduced in this table for convenient reference			
DT4.1 Institutional Accommodation	Hospitals, convalescent homes, nursing homes, old people's homes, sheltered housing	Large developments of institutional and special accommodation for vulnerable people (or that provide a protective environment) where 24-hour care is provided and where the site on the planning application being developed is larger than 0.25 hectare (Level 4)	Places providing an element of care or protection Because of age or state of health the occupants may be especially vulnerable to injury from hazardous events Emergency action and evacuation may be very difficult The risk to an individual may be small but there is a larger societal concern
	Nurseries, crèches, schools for children up to school leaving age	Large developments of institutional and special accommodation for vulnerable people (or that provide a protective environment) where day care (not 24-hour care) is provided and where the site on the planning application being developed is larger than 1.4 hectare (Level 4)	Places providing an element of care or protection Because of the occupants that may be especially vulnerable to injury from hazardous events Emergency action and evacuation may be very difficult The risk to an individual may be small but there is a larger societal concern
DT4.2 Very Large Outdoor Use by Public	Theme parks, large sports stadia and events, open air markets, outdoor concerts, pop festivals	Predominantly open-air developments where there could be more than 1000 people present (Level 4)	People in the open air may be more exposed to toxic fumes and thermal radiation than if they were in buildings Large numbers make emergency action and evacuation difficult The risk to an individual may be small but there is a

Development Type	Examples	Development Detail and Size	Justification
Note: all Level 4 developments are by exception from Level 2 or 3 and are reproduced in this table for convenient reference			
			larger societal concern

15 APPENDIX D: DEPARTMENT OF LABOUR CERTIFICATE



The certificate is a rectangular document with a green border. At the top left is the South African coat of arms. To its right is the text 'employment & labour' in green, followed by 'Department: Employment and Labour' and 'REPUBLIC OF SOUTH AFRICA'. In the center, it reads 'National Department of Employment and Labour' and 'Republic of South Africa'. Below this is 'APPROVED INSPECTION AUTHORITY' in bold. Further down is the registration text: 'Registered in accordance with the provisions of the Occupational Health and Safety Act, Act 85 of 1993, as amended.' The main body of the certificate states 'This is to certify that:' followed by the details of the approved authority: 'RISCOM (PTY) LTD', 'CIPRO Reg No: 2002/019697/07', and 'JOHANNESBURG'. Below this is a paragraph stating the authority has been approved by the Department of Labour as a Type A, Approved Inspection Authority for Major Hazard Installations under Regulations 21, 2022. At the bottom left is a signature and the title 'CHIEF INSPECTOR'. To the right of the signature are the validity dates: 'Valid from: 27 May 2025', 'Expires: 26 May 2029', and the certificate number: 'Certificate Number: CI MHI 0005'. At the bottom right is a circular seal of the Department of Employment & Labour.

 **employment & labour**
Department:
Employment and Labour
REPUBLIC OF SOUTH AFRICA

National Department of Employment and Labour
Republic of South Africa

APPROVED INSPECTION AUTHORITY

Registered in accordance with the provisions of the Occupational Health and Safety Act, Act 85 of 1993, as amended.

This is to certify that:

RISCOM (PTY) LTD
CIPRO Reg No: 2002/019697/07
JOHANNESBURG

has been approved by the Department of Labour as a Type A, Approved Inspection Authority: Major Hazard Installation under Regulations 21, Major Hazard Installation Regulations, 2022 for High, Medium and Low Hazard establishment.


CHIEF INSPECTOR

Valid from: 27 May 2025
Expires: 26 May 2029
Certificate Number: **CI MHI 0005**



16 APPENDIX E: SANAS CERTIFICATES



CERTIFICATE OF ACCREDITATION

In terms of section 22(2)(b) of the Accreditation for Conformity Assessment, Calibration and Good Laboratory Practice Act, 2006 (Act 19 of 2006), read with sections 23(1), (2) and (3) of the said Act, I hereby certify that:-

RISCOM (PTY) LTD
Co. Reg. No.: 2002/019697/07
JOHANNESBURG

Accreditation Number: **MHI0013**

is a South African National Accreditation System Accredited Inspection Body to undertake
TYPE A inspection provided that all SANAS conditions and requirements are complied with

This certificate is valid as per the scope as stated in the accompanying scope of accreditation,
Annexure "A", bearing the above accreditation number for

THE ASSESSMENT OF RISK ON MAJOR HAZARD INSTALLATIONS

The facility is accredited in accordance with the recognised International and National Standard

ISO/IEC 17020:2012 AND SANS 1461:2018

The accreditation demonstrates technical competency for a defined scope and the operation of a
management system

While this certificate remains valid, the Accredited Facility named above is authorised to use the
relevant SANAS accreditation symbol to issue facility reports and/or certificates

Mr F Osman
Acting Chief Executive Officer

Effective Date: 27 May 2025
Certificate Expires: 26 May 2029

This certificate does not on its own confer authority to act as an Approved Inspection Authority as contemplated in the Major
Hazard Installation Regulations. Approval to inspect within the regulatory domain is granted by the
Department of Employment and Labour.



ANNEXURE A

SCOPE OF ACCREDITATION

Accreditation Number: MHI0013

TYPE A

Permanent Address: Riscom (Pty) Ltd 541 Heron Place Maroeladal Randburg 2191 Tel: (011) 431-2198 Fax: 086 624-9423 Mobile: 082 457-3258 E-mail: mike@riscom.co.za	Postal Address: Postnet Suite 010 Private Bag X153 Bryanston 2021 Issue No.: 21 Date of issue: 12 May 2026 Expiry date: 26 May 2029	
Nominated Representative: Mr MP Oberholzer	Quality Manager: Mr MP Oberholzer Technical Manager: Mr MP Oberholzer	Technical Signatory: Mr MP Oberholzer
Field of Inspection	Service Rendered	Codes and Regulations
Regulatory: The supply of services as an Inspection Authority for Major Hazard Risk Installation as defined in the Major Hazard Risk Installation Regulations, Government Notice No. R2989 of 31 Jan 2025 Voluntary Supply of service as an inspection body for Hazard identification and analysis	Major Hazard Installation Risk Assessments for the following material categories: 1) Explosive chemicals 2) Gases: i) Flammable Gases ii) Non-flammable, non-toxic gases (asphyxiants) iii) Toxic gases 3) Flammable liquids 4) Flammable solids, substances liable to spontaneous combustion, substances that on contact with water release flammable gases 5) Oxidizing substances and organic peroxides 6) Toxic liquids and solids Hazard identification and analysis including HAZARD of and operability studies (HAZOP)	MHI regulation par. 5 (5) (b) i) Frequency/Probability Analysis ii) Consequence Modelling iii) Hazard Identification and Analysis iv) Emergency planning reviews Reference Manual Bevi Risk Assessments version 3.2 (2009) CPR 18E (1999), Guideline for quantitative risk assessment ("Purple Book"), TNO Apeldoorn. CPR 14E (1997). Methods for the Calculation of Physical Effects ("Yellow Book"), 3 rd Edition, TNO, Apeldoorn. CPR 16E (1992). Methods for the Determination of Possible Damage ("Green Book"), 1 st Edition, TNO, Apeldoorn. Lees FP (2001). Loss Prevention in the Process Industries: Hazard Identification, Assessment and Control, 2 nd Edition, Butterworths, London, UK. SANS 1461 SANS 31000 SANS 31010

Original date of accreditation: 27 May 2005

Page 1 of 1

ISSUED BY THE SOUTH AFRICAN NATIONAL ACCREDITATION SYSTEM


Accreditation Manager

17 APPENDIX F: MATERIAL SAFETY DATA SHEETS (MSDS)

17.1 Liquefied Natural Gas (LNG) (CAS No.: 74-82-8)

17.2 Natural Gas (CAS No.: 74-82-8)

17.3 Ammonia (CAS No.: 7664-41-7)

17.4 Helium (CAS No.: 7440-59-7)